PICTORIAL INTRODUCTION TO NEUROLOGICAL SURGERY

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BY

G. F. ROWBOTHAM

AND

D. P. HAMMERSLEY

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TO

CHARLES MACMILLAN

TO WHOM

MEDICAL PUBLISHING

AND

MANY AUTHORS

OWE SO MUCH

"A thing of beauty is a joy for ever; . . .
Its loveliness increases;
It will never pass into nothingness."

KEATS.

ACKNOWLEDGMENTS

THE Surgery on which this book is based was carried out in the neurosurgical operating theatre at the General Hospital, Newcastle-upon-Tyne. For the generous surgical facilities that have been accorded we are grateful to Dr. W. G. Patterson, the Senior Administrative Medical Officer of the Regional Hospital Board, Region 1, and to the Management Committee of Area 1, Region 1.

It is the liaison that exists between Neurological Surgery and the Department of Surgery in the University of Durham that has made this work possible, and we extend our thanks to Professor R. B. Green, the Dean of the Medical School, for affording us access to the research facilities of the Medical School.

Dr. Kathleen Bell and Sister E. Hetherington have helped us substantially in the preparation of the chapter on a surgical theatre technique, and we thank them. In the presentation of the text and in the setting up of the book we are grateful to Miss Marjorie Bousfield, Miss Audrey Pollock and Miss Moira Jobey for all the assistance they have given us. We also thank Mr. J. E. Rogers of the Department of Surgery for all the "tips" and invaluable help he has given us.

Finally, we are indebted to Mr. Charles Macmillan, whose enthusiasm and encouragement have been an inspiration to us since the book was first planned.

G. F. R.
D. P. H.

SURGEON'S PREFACE

THE surgical requirements of social life are changing; already new developments compel us to contemplate the possible demands of future catastrophes that might result from atomic explosions in industry or in warfare.

The time may be propitious, therefore, to inquire into the modern trend of surgery and particularly in relation to the problem of trauma. The conditions of accident are such that when the head is injured, the bones and tissues of the face and other parts of the body are also liable to injury. Indeed, although the skill of a neurological surgeon is primarily needed on a head injury unit, the help and co-operation of other specialists practised in trauma are essential if the best results for the patient are to be obtained. In the University centres and in the larger towns, surgical specialists in many fields are actively engaged in their occupations and the particular problems of trauma are adequately cared for. However, the volume and scatter of head and facial injuries are such that departments for the treatment of this type of injury are also needed in outlying areas in most regions.

It would be uneconomic to supply every clinic for the treatment of trauma with a multiplicity of specialists, and soon one man of many specialist skills may have to be trained to fill the more outlying of the posts. It was with this need in mind that this monograph was first envisaged and its format devised. Most British neurological surgeons of the past and present have stemmed from general surgery and all future ones are most likely to do the same. Therefore, since neurological surgery owes so much to general surgery, a feed back of some of her special experiences to the general fund might be as good a gesture as any of expressing appreciation for the earlier benefits received.

All concerned in post-graduate teaching are agreed that the training of a pupil must, in the early stages, be governed by broad concepts and that purely technical embellishments must come later in apprenticeship. Trauma surgeons of the periphery must be trained in the University centres and retain at least an associate status with them.

I have had repeated requests from many of my pupils now in general or special branches of surgery to publish the surgical techniques they have seen used in my neurosurgical clinic. I think everyone of experience will know that to describe the details of surgical technique is one of the most difficult of exercises and one of the most boring. However, I have been prevailed upon to make the effort and I have sought my solution pictorially.

A work of this nature could not be comprehensive; it was not meant to be so, but to quote a very descriptive expression of a late Professor of Surgery of the University of Durham, R. J. Willan, we hope that this work can be utilised as a series of "hat-pegs".

The early chapters on theatre technique may be thought to be unduly simple and possibly unnecessary, but it is my firm belief that until one can render the actual manipulations of neurological surgery relatively easy, good results are exceedingly difficult to obtain.

This volume ends with a chapter on the surgical aspects of cerebral trauma, and meantime the operative techniques of pain and of tumour surgery are omitted. We are confident, however, that the work will prove of value to all interested in surgery.

G. F. ROWBOTHAM

DEPARTMENT OF NEUROLOGICAL SURGERY, REGION I
AND UNIVERSITY OF DURHAM
1953

ARTIST'S PREFACE

TO describe in detail the intricacies of neurosurgical technique by means of pictures presents many difficulties. The task of the illustrator is not merely that of realistically representing the various structures within a field of operation: he must also tell a story. In order to do this, the composition of each illustration must be planned in such a way that attention is directed towards the important parts of each picture and the eye led naturally from one illustration to another.

Generally speaking, the most useful pictures are obtained by accurate and artistic draughtsmanship. In the recording of operative techniques, photography, particularly still photography, is often inadequate primarily because the camera cannot differentiate between the important and unimportant aspects of a complicated surgical exposure. The artist's representation, on the other hand, is a product of intellect and intuition. A continuous impression is recorded on his mind during the operation, and into this impression is merged his knowledge of anatomy, his understanding of the basic principles of the operation, and his intuitive ideas about picture-making. The finished illustration is a synthesis of all these elements.

In the present work various styles of drawing have been employed. For example, those pictures dealing with positioning and towelling have been drawn with a pencil, because I believe that there is a natural sympathy between the texture of pencil shading and the texture of light and shade on draped towels. A more elaborate half-tone technique has been used in the drawing of operative exposures, so that glistening fat and fascia, yielding brain tissue and the hard glint of instruments may be represented with convincing realism. Pen-and-ink drawing has been confined to illustrations of surface conditions, apparatus, and the diagrammatic pictures where simplification was desirable.

Where it has been necessary to illustrate a complete manœuvre, our aim has been to dissect the manœuvre into a connected series of simple steps seen, so far as possible, from a fixed viewpoint, and to make a detailed drawing of each stage. These drawings have then been arranged in sequence on one or two pages so that the whole procedure can readily be followed.

Above all, we have tried to make our illustrations accurate, concise, and pleasant to study.

D P HAMMERSLEY

DEPARTMENT OF SURGERY
UNIVERSITY OF DURHAM
1953

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Chapter I

POSITIONING AND TOWELLING

ANY major surgical procedure devolves into the three stages of preparation of the patient, the operation and post-operative care. Without proper pre- and post-operative care, the results of the most painstaking and skilled surgical technique may be spoilt. It is obviously wrong to bring a patient into the operating theatre unnecessarily shocked, short of blood, unduly apprehensive or suffering from intolerable pain. Also it is equally foolish to let a patient asphyxiate after he has been sent back to the ward, or to pick at his wound and make it septic. Much has been written on these two most important subjects of pre- and post-operative care, and it is therefore our intention largely to concentrate on the aspect of surgical approach and technique. It is our belief that this object can best be obtained pictorially, and we propose to illustrate in such detail that each stage of the operation is made clear. Also, in order to emphasise those points which we think important, we shall not hesitate to repeat verbal or pictorial statements or advice.

Our first series of pictures deals with the main steps in theatre technique from the moment a patient is wheeled into the anæsthetic room until he is in position on the operating table and everything is ready for the primary incision. Particular emphasis has been given to the method of towelling, and we have illustrated each stage in considerable detail; this has been done even at the risk of over-simplification. Our experience has taught us that it is on the failure to observe what appears to be a trivial technical point that the smoothness of an operation is often wrecked. Also in the attempt to eliminate sepsis it is wrong to be meticulously careful with nine possible factors and to be careless with the tenth. It is not our wish to give the impression that our ways are the only ways, but we trust that our method of preparing the operating table and our theatre set-up will contain useful suggestions to those about to embark on the multitudinous layouts of neurological surgery.

The natural apprehensions of a patient can usually be readily allayed if, on his arrival in the anæsthetic room of the surgical block, he is received by an anæsthetist who has already examined him and understands the nature and severity of his illness. Also it is much more reassuring to the patient to realise that all the anæsthetic apparatus is ready than to hear hurried instructions for its assembly. Indeed careful pre-operative planning of the anæsthesia and adequate nursing assistance for the anæsthetist is a major part of the whole operative manœuvre. Without perfect anæsthesia an extensive operation on the head is unlikely to succeed.

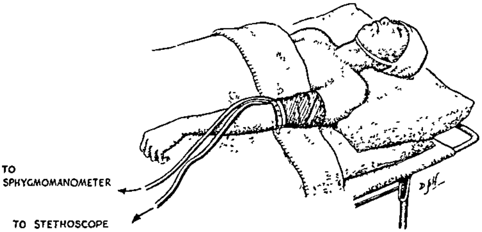

FIG. 1

A blood pressure reading is taken immediately before the induction of anæsthetic.

In the first instance the sphygmomanometer cuff and diaphragm are secured and a blood pressure reading recorded (Fig. 1). To have to disturb the drapes later in order to fix the blood pressure apparatus is not only an inconvenience but a danger to asepsis. Also an immediate pre-operative blood pressure record will not have been taken, with which post-operative comparisons can be made.

No effort must be spared or detail of technique neglected to procure smooth induction of anæsthesia. Straining, coughing or anoxæmia may result in fatal hæmorrhage into the brain. Unless a free airway and proper control of the interchange of gases are obtained and maintained, imperfections of breathing occur that cause venous congestion and swelling of the brain. No greater depth of anæsthesia is needed than is necessary to abolish the appreciation of pain.

By the time an operation is completed a patient should be well on the way to consciousness regarding the effect of the anæsthetic, otherwise a surgeon is unable to assess what effect his own manipulations have had on the conscious level of his patient. When the diathermy current is to be used it is advisable that the anæsthetic mixture used should be non-inflammable

One of the greatest advances in neurological surgery in the past twenty years has been that of neuro-anæsthesia (Fig. 2).

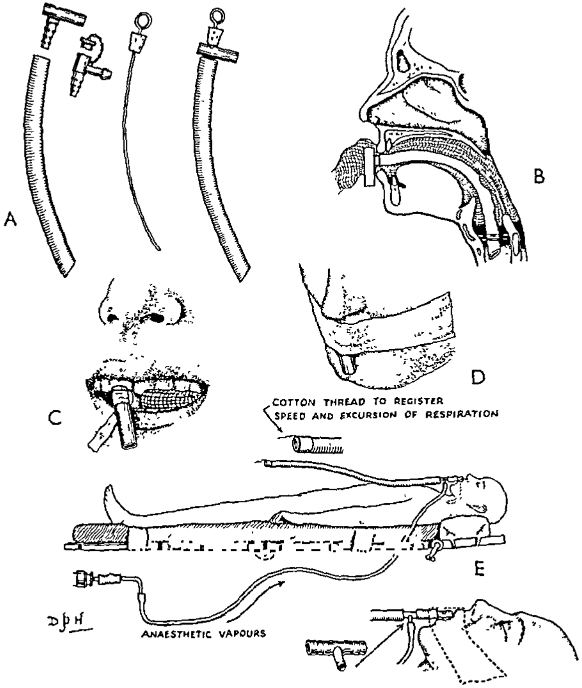

FIG. 2

Endotracheal Intubation

A Assembly of the intratracheal tube and attachments. B. An intratracheal tube must be so placed that its end projects just beyond the vocal cords in any position of the head. C A gauze roll placed between the teeth prevents biting and kinking of the tube. D Firm anchoring of the intratracheal tube is essential: otherwise if the head is moved the tube will be pulled out of position with serious consequences. E. Ayre's tube.

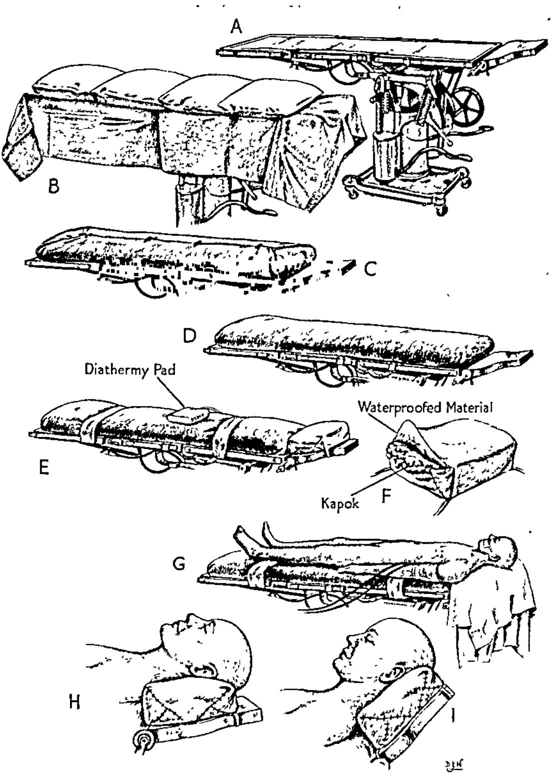

FIG. 3
Preparation of the Operating Table

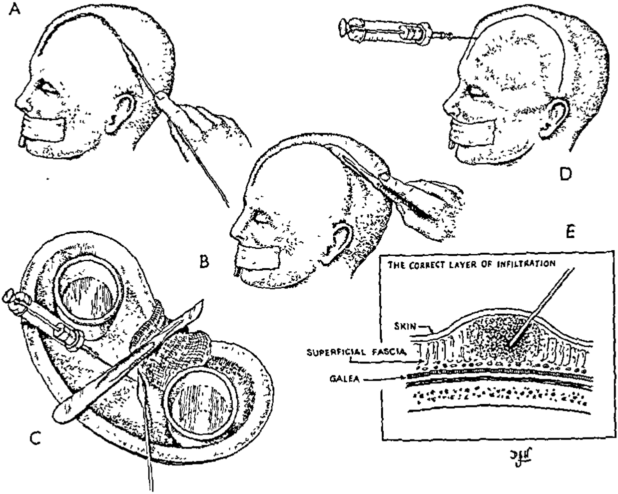

FIG 4
Outlining of the Incision

Though it is preferable to use specially constructed neurosurgical apparatus, most present-day operating tables can, by simple means, be made adaptable for head surgery. To prevent pressure sores and to minimise post-operative discomforts, a patient's weight as he lies must be evenly distributed and his neck muscles must not be stretched excessively. A satisfactory bed can be made by pinning four pillows, laid side by side, in a sheet. The bed is placed smooth side upwards and strapped to the table for obvious reasons. Suitable head-rests can easily be constructed by moulding kapok into the required shape and sewing it in a waterproof covering (Fig. 3).

In the interests of asepsis a patient's scalp should not be touched by the surgeon's hands. The line of incision is drawn in iodine, a suitable pencil being made by twisting a wisp of cotton wool around a wooden probe. When the final line has been decided upon, it is etched with the back edge of a scalpel blade so that it will remain visible should the iodine line of choice be washed away. Local anæsthetic containing adrenalin is injected along the proposed line of incision. A tray to carry the apparatus tends to ensure that the necessary instruments and solutions are always ready (Fig. 4).

DRAPING OF THE TOWELS

The object of towelling is to reduce possible sources of infection to a minimum. It is important that towels be so arranged that they keep in place even though the head of the patient be moved in relation to his body. There is nothing more disturbing than the tendency of drapes to drag out of position and to restrict a surgeon's movements.

The functions of an overhead table are:

1. To separate and shut off the operation field from the anæsthetic zone of activity.
2. To act as a suitable rest for the operating instruments.
3. To allow the drapes to be lifted from the face when operating under local anæsthesia.
4. To permit observation of the patient's face and body.
5. To allow access to the limbs for venesection.

A mackintosh sheet covered with a sterile towel is first placed beneath the head of the patient. The head is then covered with a sterile sheet of lint that has been moistened in an antiseptic solution. The nose and mouth are then covered with a thick mackintosh sheet. If towels are moistened in antiseptic before they are placed in position, they more easily mould to the shape of the head and have less tendency to slide out of position. Moreover, the antiseptic acts as a further barrier against infection as the field of the operation becomes wet with saline or blood. If the towels are not moulded to the shape of the head, the surgeon's later movements can easily be obstructed by a tight edge of a towel. To prevent slide, the deeper towels are not only clipped to each other but to the lint sheet, which in its turn is stitched firmly to the scalp. The deep towels must be firmly anchored if the overlying sheets are to stay in their correct positions.

The importance of correct and adequate towelling can scarcely be over-emphasised. The various stages and the end result are depicted on the opposite page.

(*a*) The overhead table is fixed in position. A sterile sheet of lint covers the head

(*b*) A mackintosh sheet and linen towel are draped over the nose and mouth.

(*c*) and (*d*) Further towels are placed around the head, and the whole of the drapery is moulded to the shape of the head and firmly anchored.

(*e*) A large linen towel which entirely surrounds the proposed field of operation is placed over the deeper towelling. The overhead table is draped.

(*f*) The head of the operating table is screened off.

(*g*) An opening is cut in the lint sheet and the proposed field of operation is exposed. The cut edges of the sheet are then folded under and firmly stitched to the scalp.

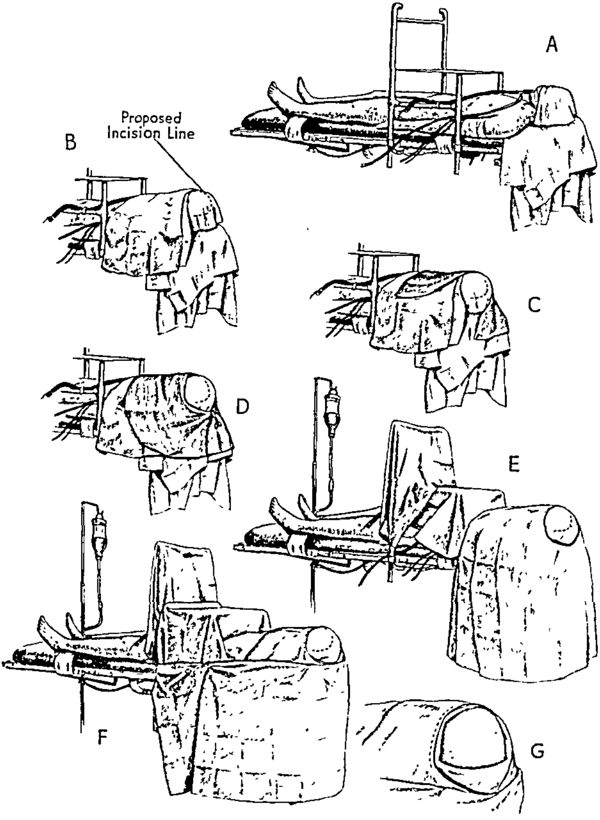

FIG. 5
Draping of the Towels
(See p. 6)

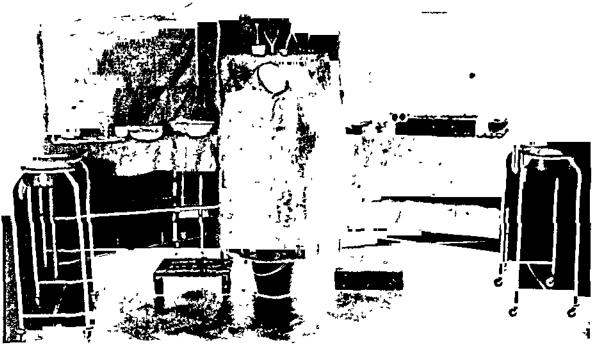

FIG. 6
The Theatre Set-up

FIG 7
The Operating Team in Position

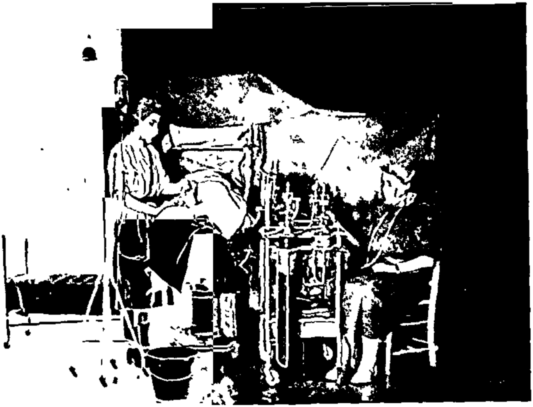

FIG. 8
The Anæsthetic Field

It is desirable that the theatre set-up should be such that the operation field is shut off from the zone of activity of the anæsthetist who nowadays is so often engaged in arteriotomy or venesection (Fig. 6). For smooth and rapid working it is better for the anæsthetist to have a nurse or nurses allocated to assist him in his work, distinct from those that give service to the operating team (Figs. 7 and 8).

The patient's position must be such that the surgeon and his team can sit or stand in an easy position and operate in comfort. The serving staff must also have access to the operation field without having to walk amongst the operating team. Diathermy and suction apparatus should be so placed that they can be brought into use without delay, with neither apparatus nor cables impeding free movement about the theatre.

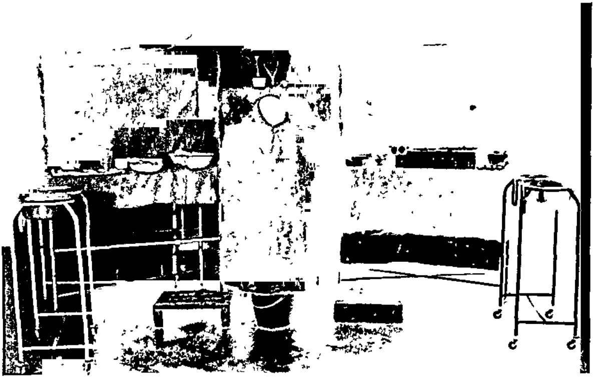

FIG. 6
The Theatre Set-up

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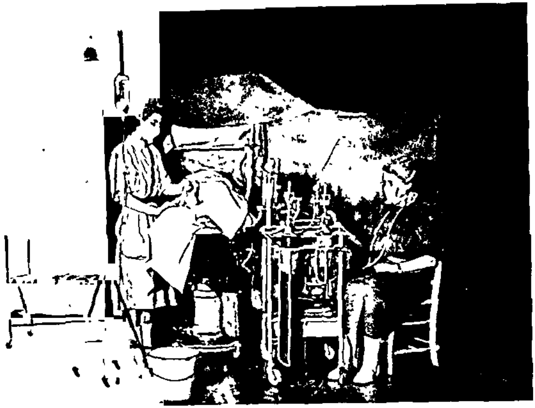

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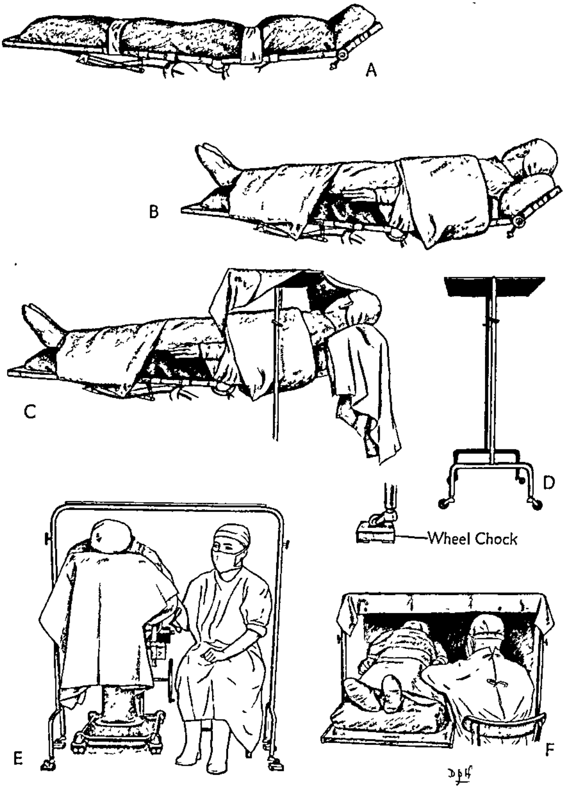


Fig 9
Operations under Local Anæsthesia

When preparing to operate under local anæsthesia it is most important to ensure that the patient is comfortable. Whilst it is essential for the arms to be securely strapped, movement should not be so restricted as to cause the patient unnecessary mental suffering. The towels should be draped in such a way that adequate ventilation is provided: restlessness, overheating, and even suffocation may result if a free airway is not present. It is also important to allow sufficient space beneath the towels for the anæsthetist or his attendant to have a clear view of the patient's face during the operation. This contact will help to promote a sense of security on the part of the patient (Fig. 9).

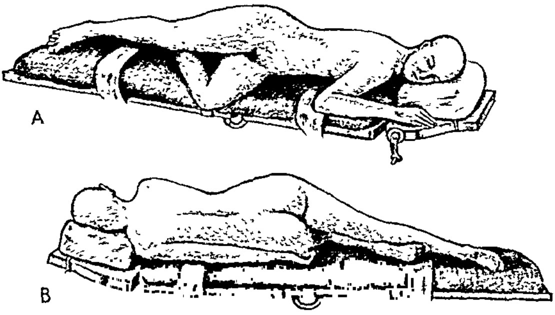


FIG. 10

The Lateral Position

If the limbs of a patient are placed in the positions shown in Fig. 10, the patient's body will not only rest in the position in which it has been placed but there will be no danger of nerve or arterial compression

The advantages of the lateral position are: 1. The back of the head can be turned upwards without recourse to putting the patient on his face and impeding respiration 2. Lumbar puncture can be carried out during an operation when lumbar drainage is thought necessary—for example, in compound wounds of the brain.

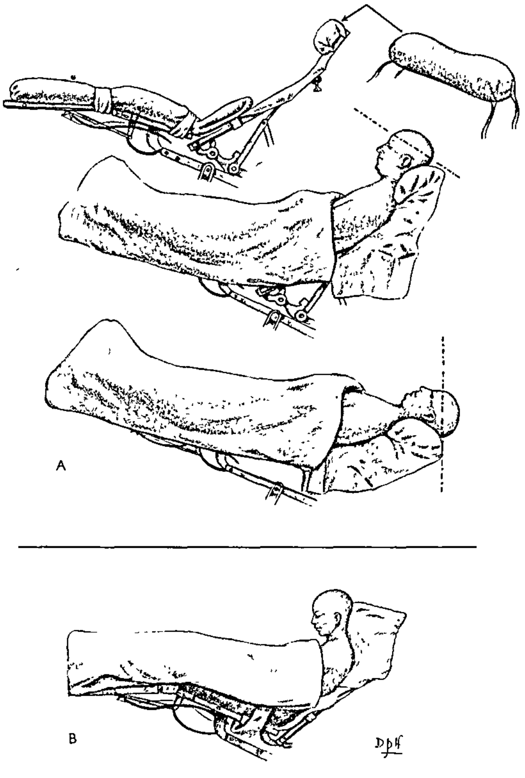


Fig 11

Special Positions

A Ventriculography. B Trigeminal posterior root section

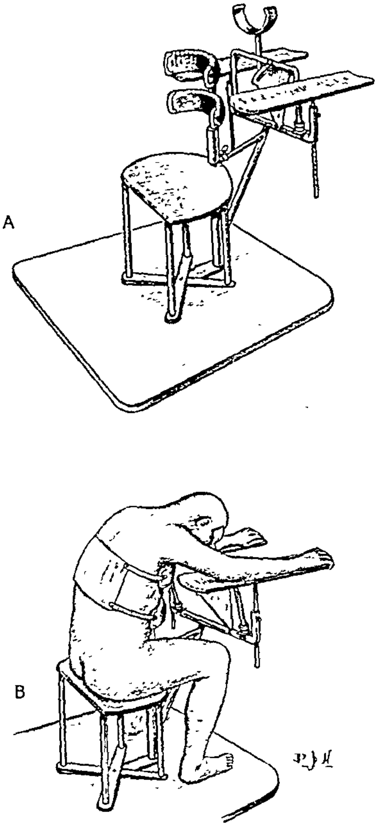


FIG. 12

The Newcastle Chair and the Sitting Position

The sitting position produces the most favourable conditions for operations in the posterior fossa and on the cervical spine.

This table was designed by G. F. Rowbotham and N. Whalley

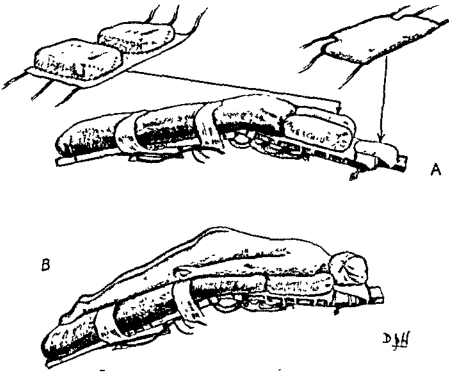


FIG. 13

The Position for Lumbar Laminectomy

By b[illegible]
can [illegible]
Pad[illegible]
and pelvis and not on his chest and abdomen, as this will impede breathing and produce congestion in the operation field

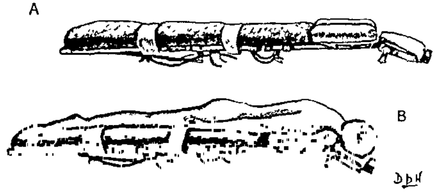


FIG 14

The Position for Dorsal Laminectomy

Operation on the dorsal spine may be made with the patient either in the sitting or prone position When lying, it is not necessary to break the operation table.

Chapter II

SURGERY OF THE SCALP

WHEN a major operation on the head is contemplated it is best to shave the whole of the scalp; shaving must be close and skilful. Small wounds caused by scraping of the razor are apt to go septic. On those occasions when it is deemed unnecessary to remove all the hair, the areas cleared should be wide rather than skimpy. The remaining hair is strapped under control to prevent it blowing into the operation field. After the head is shaved the scalp is washed with soap and water and then treated with a mild antiseptic detergent. No kind of antiseptic should be used that tends to burn or dehydrate the skin. We would like to emphasise that skilled operations are easily marred by imperfect preparation of the scalp.

An arm and leg is also prepared for venesection and fascial grafting. The areas prepared are wrapped in sterile compresses. It is permissible to prepare the head the night before operation. When much head-work is a routine activity the services of a skilled barber is a justifiable expense.

A scalp flap must be so shaped and positioned that *(a)* its furthermost edges remain vascularised, otherwise necrosis and sepsis will result; *(b)* it gives satisfactory access to the deeper tissues that it is proposed to uncover; *(c)* the scar will not interfere with the fundamental design of a larger flap that might be necessary in the future; *(d)* disfigurement is minimal.

During the actual cutting and raising of the flap every surgical manœuvre that minimises bleeding must be employed. If suitable precautions are not taken even the reflection of a small flap may result in so great a blood loss that the patient's reserves of strength are depleted before the deeper and more important stages of the operation are arrived at. If primary healing is to be obtained, skin edges must neither be bruised with forceps nor burnt with diathermy currents.

In the debridement of open wounds the cutting away of ragged skin edges must always be done sparingly. For the best results it is necessary to end with a complete covering of the head with sound skin that is not attached to bone or to deeper tissues.

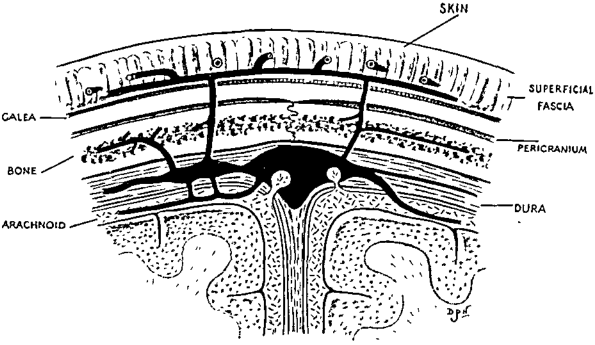


FIG 15
The Brain-Scalp Circulation

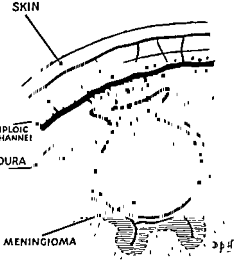


FIG 16
Congestion of the Brain-Scalp Circulation due to a meningioma

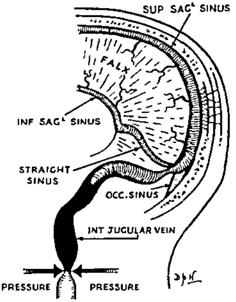


FIG. 17
Congestion in the head due to constriction of the internal jugular veins

THE BRAIN-SCALP CIRCULATION

The veins of the brain drain into the large dural venous sinuses and thereby enter the internal jugular veins. Each dural sinus, however, is also connected with the extra-cranial circulation by channels that issue through the basal foramina and by the diploic veins of the skull. It is the importance of the connecting circulation of the brain with the scalp through the diploic channels that we wish particularly to emphasise, since it is this phenomenon that produces most of the surgical difficulties of exposing the brain and thus conditions neurosurgical techniques. Whenever the venous blood pressure in the head is raised, the brain-scalp circulation becomes engorged; the veins draining the cortical veins into the venous sinuses dilate; the venous sinuses fill, the diploic circulation is speeded up and the scalp with its communicating channels becomes engorged. Whenever the brain-scalp circulation is engorged, surgical manipulations, without special precautions, may be attended by so severe a blood loss that not only are the steps of the operation obscured, but the life of the patient jeopardised (Fig. 15).

Causes of Congestion in the Brain-Scalp Circulation

1. Space occupying lesions which, by their mass, compress or displace the terminals of the main venous sinuses.
2. Generalised cerebral œdema, such as occurs in acute pyogenic infections of the brain.
3. The increase in the circulation of the more malignant of the gliomata, such as the glioblastomata, without the protection of an adequate capillary bed.
4. Meningiomata, with their peculiar blood supply from the venous side of the cerebral circulation (Fig. 16).
5. Arterio-venous aneurysms of the brain and scalp.
6. Faults in anæsthesia causing straining or anoxæmia.
7. Faults in positioning so that the head is lower than the rest of the body.
8. Compression of the internal jugular veins by constricting bandages or clothes (Fig. 17).

Whenever an operation on the head is contemplated, every effort should be made to lessen the brain-scalp circulation by suitable positioning, correct anæsthesia, dehydration and venesection or arteriotomy. It cannot be over-emphasised that the ease and success of an operation so often depends on the care that has been taken to produce the conditions for non-congestion. Even in those cases where the brain-scalp circulation is minimal and the dural sinuses are relatively empty, no license can be taken with the minutæ of neuro-surgical technique if severe blood loss is to be avoided.

Superficial Fascia

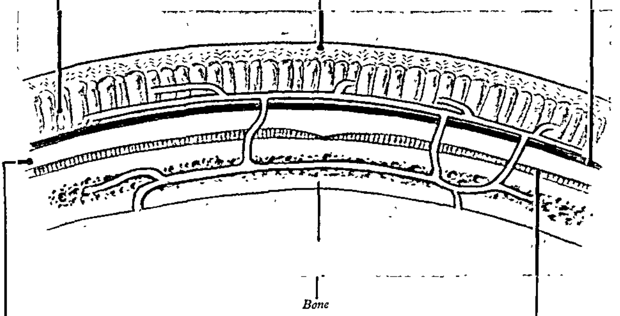
The superficial fascia binds the skin proper so firmly to the underlying galea that no movement is possible between the two layers. Fibrous bands localise extravasations of fluid but tend to prevent cut blood vessels from contracting and clotting

The Galea Aponeurotica

or tendon of the occipito-frontalis muscle is attached directly or indirectly to the whole of the circumference of the base of the calvarium, thus forming a fibrous tissue envelope for the

Skin

The skin of the scalp is very richly supplied with blood vessels and with nerves: therefore incisions into the scalp are apt to bleed profusely and lead to shock from pain if suitable precautions are not taken



Loose Areolar Tissue

The looseness of the attachment of the areolar tissue both to the galea and to the pericranium allows the skin to slide smoothly over the surface of the skull. This phenomenon is of great surgical importance since it allows closure of a wound in spite of tissue loss Also it exists as a potential space where considerable bleeding can occur and in which infection can spread widely

Pericranium

The pericranium or external periosteum is firmly attached to suture lines but fairly readily separable elsewhere

FIG 18

The Layers of the Scalp

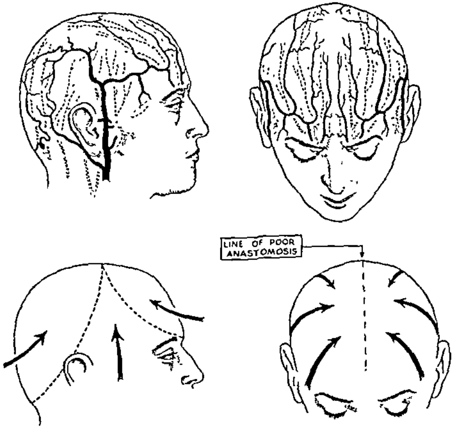


FIG. 19

The Vascularisation and Innervation of the Scalp

On each side of the head there are three main streams of supply—from the frontal region, the temporal region and the occipital region. The vascularity is richest at the base of the scalp, diminishing towards the vertex. A line of poor anastomosis runs along the vertex from the nasion to the occiput.

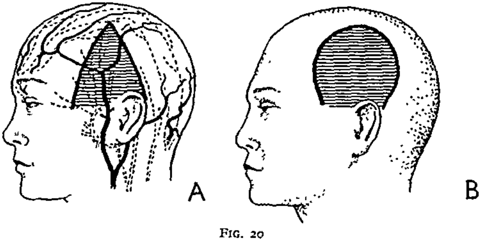


FIG. 20

The Principles of Skin Flap Design

Ideally, a flap must have a broad base situated low on the scalp where the supply of blood vessels and nerves is richest. It should taper as it approaches the vertex, which it should not transgress.

The ideal flap is shown in Fig. 20, A. The flap in Fig. 20, B, is based on the ideal flap, but also satisfies the surgical requirements of adequate exposure and easy closure.

It should be a surgical axiom that one should never attempt to reflect a large skin flap until adequate assistance is assured and operating conditions are right. In the first instance too much care cannot be taken in the designing of the flap: outlining is best done before *the head is covered with towels, when orientation is easiest. There is no reason why* a skin flap should not be wider and higher than the bony entrance envisaged, since it is always desirable that a scar should lie well beyond a bony edge over intact bone. The line of incision and its baseline should be thoroughly anæsthetised with novocain-adrenalin solution, especially when an operation under local anæsthesia is intended. In such a case, when anæsthetisation of a temporal incision line is the aim, it is most important to ensure that the solution is freely infiltrated over a wide area so that the whole of the temporal muscle may be made insensitive.

When reflecting a skin flap, bleeding from its cut edges can always be readily controlled by finger pressure, followed by suitable clamping with Spencer-Wells forceps or Michel clips. On the other hand, one must always be prepared to deal with bleeding from the under surface of the flap or from the uncovered bone or muscle. On reflecting the flap it is most essential to avoid buttonholing its base, otherwise important blood vessels or nerves may be unnecessarily severed. When operating low on the forehead, care must be taken not to damage the eyeball should an instrument inadvertently slip.

The object of two layers of sutures with a buried layer in the galea is primarily to give strength to the closure. Also the sutures are useful in serving a hæmostatic function, especially since it is scarcely possible to tie each cut vessel separately. With properly placed deep sutures, accurate apposition of the skin edges is ensured. Care must be taken to cut the deep sutures close to the knot, as long ends will act as foreign bodies and project beyond the skin edge to prevent primary healing.

Correct and neat bandaging not only has a beneficial psychological effect on the patient and staff, but is also a surgical necessity. A bandage must be comfortable and stay easily *in position, otherwise it will slip* or *be removed by a semi-conscious patient, and the wound* exposed to sepsis. Care must be taken not to constrict the jugular veins in those cases when it is necessary to encircle the neck with a bandage to keep it in position, such as happens in cerebellar exposures.

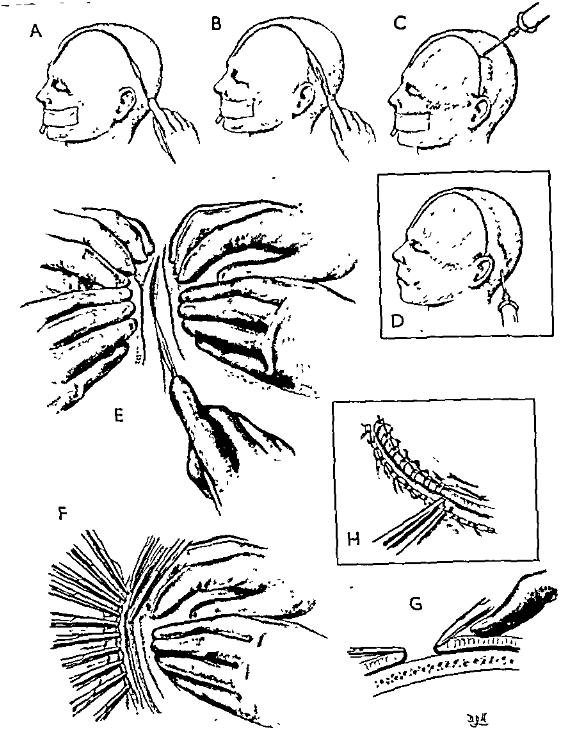


FIG 21

Reflection of a Skin Flap (1)

A, B, C. Outlining and anæsthetisation of the proposed in [illegible] scalp is necessary when an operation under local anæsth[illegible] by digital compression as the incision is made F, G. [illegible] forceps at intervals of half-an-inch. It is unnecessary [illegible] since the drag of the artery forceps will produce satisfactory hæmostasis when they are turned backwards over the edges of the wound. H. An alternative method of hæmostasis is to clamp the skin edges with Michel clips.

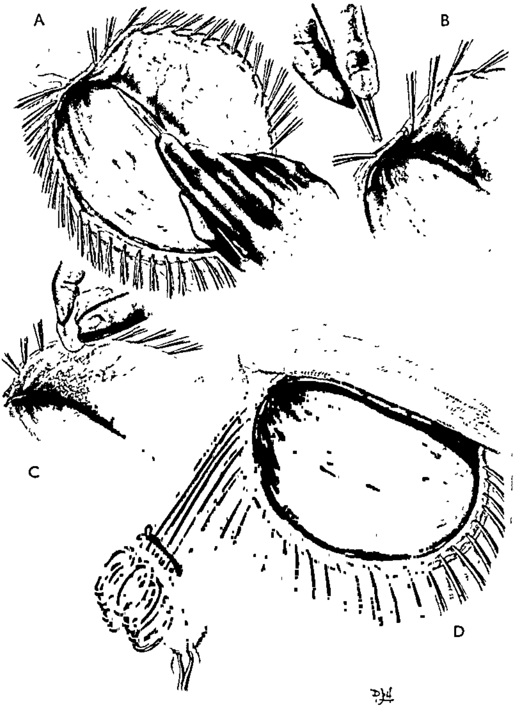


FIG 22

Reflection of a Skin Flap (2)

A Separation of the galea from the [illegible]

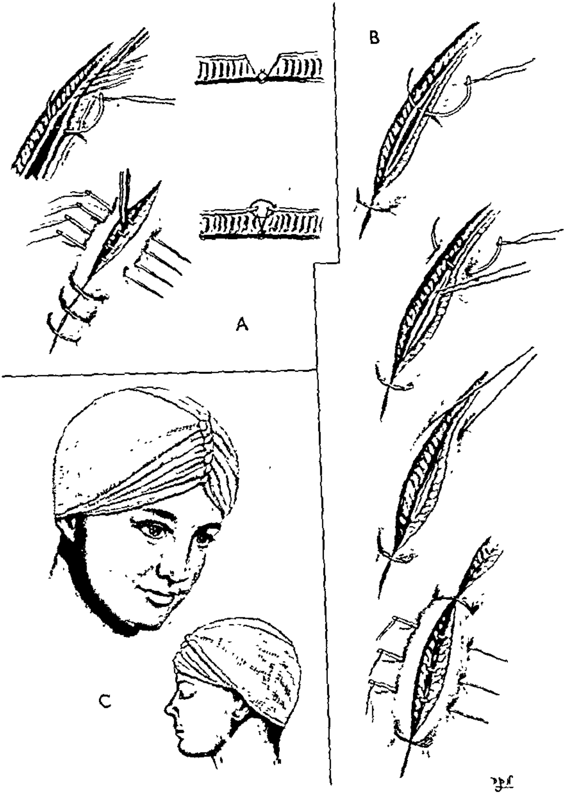


FIG. 23

Closure and Bandaging

A and B. Different methods of two-layer closure. C. The Newcastle head bandage.

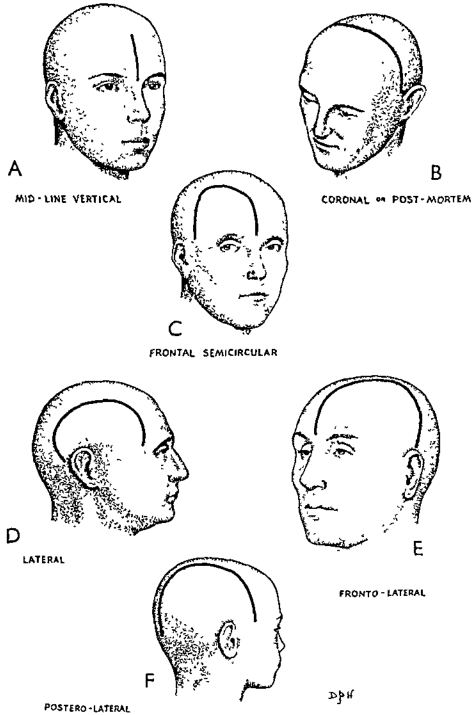


FIG. 24
The Approaches to the Calvarium

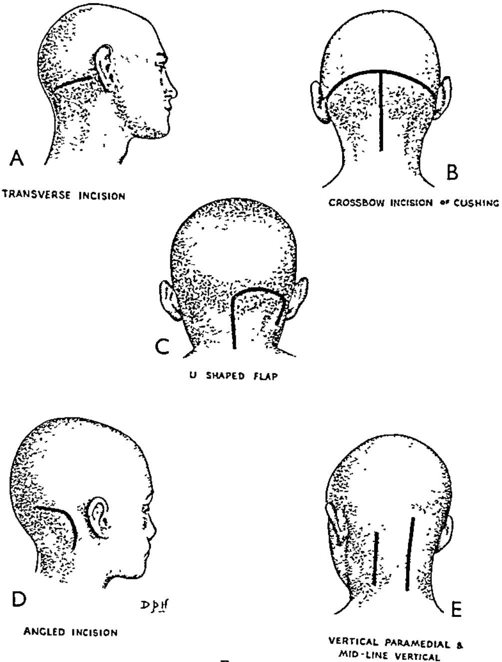


FIG. 25

Classical Approaches to the Posterior Fossa

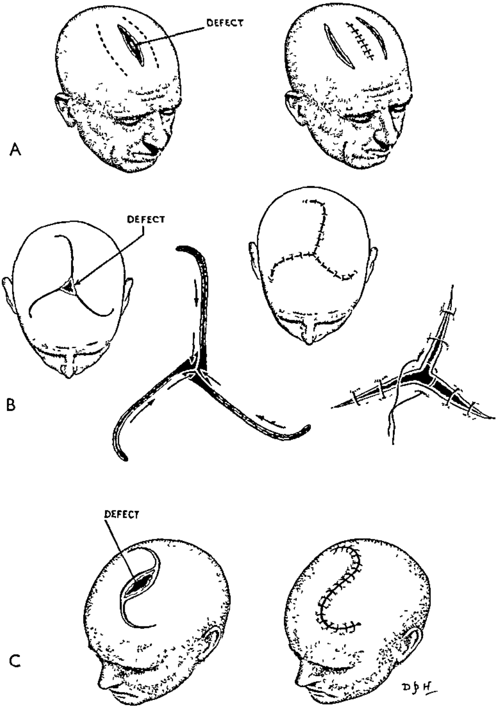


FIG. 26

Plastic Operations on the Scalp (1)

A. Relaxation incisions B. Triradiate incisions of Cushing. C. S-shaped incision.

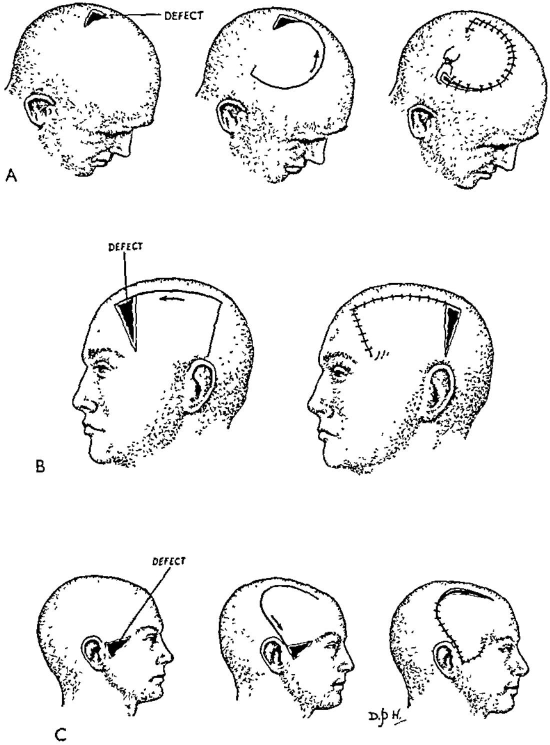


FIG. 27

Plastic Operations on the Scalp (2)

A, C. The rotational flap of Gillies. B. The quadrilateral flap.

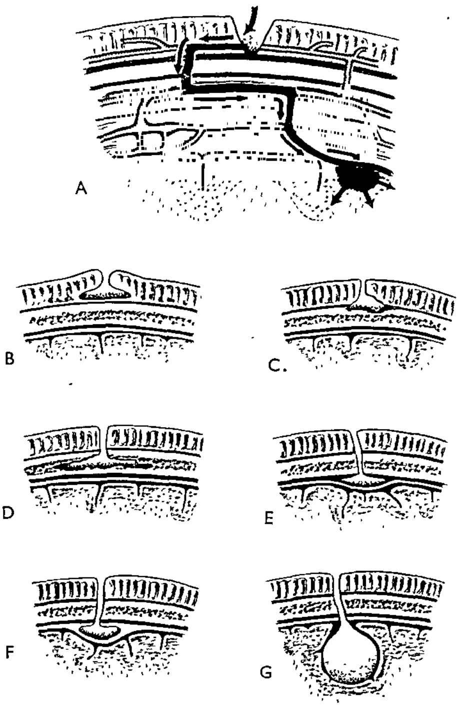


Fig. 28

Routes of Infection

A A route of infection. B An abscess of the scalp C. Superficial periostitis. D. Osteomyelitis. E An extradural abscess F An interdural abscess. G An intracerebral abscess.

Chapter III

SURGERY OF THE SKULL

THE technique of surgery of the skull is conditioned by the toughness of bone and its limited elasticity, and by the anatomical peculiarities of its circulation. For its own metabolic processes it is supplied from below by meningeal vessels and from above by vessels of the fibro-muscular attachments. However, and more important surgically, the bony channels constitute the middle limb in the brain-scalp circulation. Therefore there is a great tendency for bone to bleed whenever it is separated from the scalp or dura and when it is in the process of being cut. Indeed, bleeding from the cutting or exposure of a bone flap may often be so severe that it is quite impossible to continue with the operation to expose the pathological lesion in the brain. For the cutting of bone special instruments of course are necessary, and these must be sharp, strong and safe. Also, it must be possible to re-sterilise them safely and quickly for further use, or should they inadvertently become soiled. Opening the head with a trephine and subsequent replacement of the bone disc is a useful method of exploring the intracranial cavity when for cosmetic, social or legal considerations it is undesirable to leave a patient with a defect in his skull. To obviate heavy hand- and wrist-work, a trephine can now be fitted to a brace. The present method of opening the skull is first of all to sink holes by means of a perforator and burr at suitable points, and to link these with saw cuts. Alternatively, it is sometimes more convenient to join up the holes by cutting between them with a de Vilbiss forceps. When only a limited exposure is desired, the usual practice is to sink a single burr hole and to widen it by biting the bone away with nibbling forceps. Holes can be made either with mechanically driven drills or by means of a hand brace, and in the case of electric drills adjustable stops can be fitted which will prevent too deep a penetration and damage to the brain should the instrument plunge or slip.

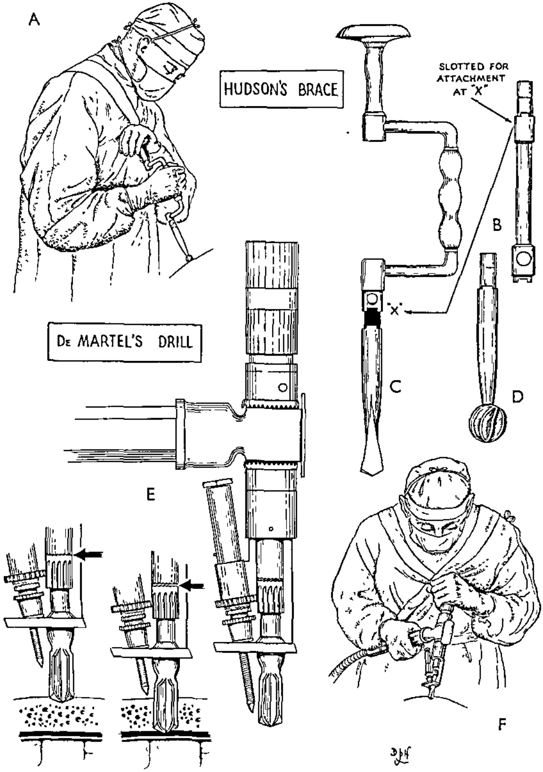


FIG. 29

mechanism becomes engaged As soon as the bone is pierced and the non-resisting soft tissues reached, a spring throws out the mechanism and the drill ceases to rotate.

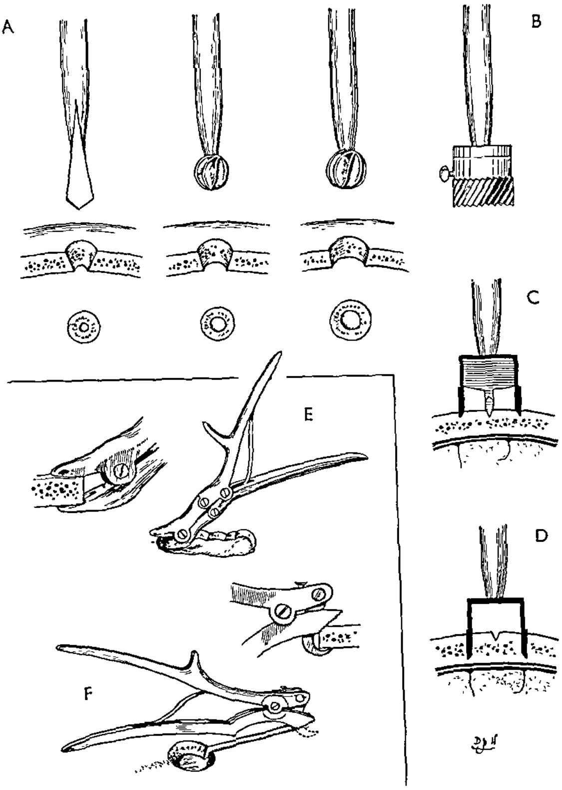


FIG. 30

A The perforator and burrs. B Trephine. C. Cutting with a trephine; the central pin in position. D. The central pin removed. E. Double-acting nibbling forceps. F. De Vilbiss forceps.

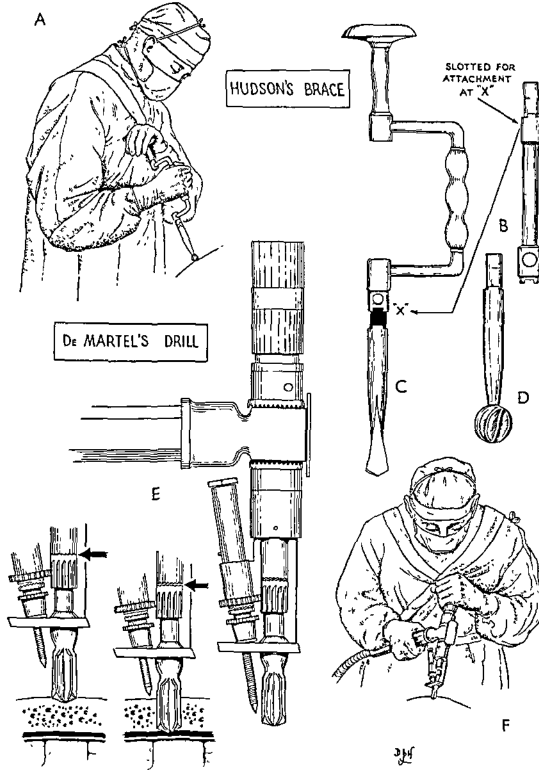


FIG 29

A The brace is held in a position of ease. As undue pressure is dangerous, the shoulder muscles should be locked so as to keep the instrument under control and prevent it inadvertently plunging into the brain B An extension apparatus for use in cases of deep cerebellar wounds C. A perforator D A rounded burr E, F When the drill is thrust against bone the driving mechanism becomes engaged. As soon as the bone is pierced and the non-resisting soft tissues reached, a spring throws out the mechanism and the drill ceases to rotate.

When a bone flap is raised its blood supply from the middle meningeal vessels is severed. Therefore if the bone is to remain viable the covering muscle or fascia must be left attached, otherwise the only remaining source of blood will be cut off. In such cases the bony flap, when replaced, acts as a dead graft. The usual way of preserving continuity between muscle and bone is to reflect a bone flap on a hinge of muscle. This condition is obtained by cutting the fibro-muscular covering of the vault of the skull in the shape of a horseshoe, the open end of which provides the hinge. After the bone has been sufficiently cleared of pericranium to admit the perforator, holes are drilled at convenient intervals of about three inches. The holes are widened with a burr and debris washed clear. Bleeding from the bone is stopped by plugging the holes with Horsley's wax. After the holes have been sunk, the dura mater is eased from the bone with a curved metal separator (curved Adson dissector) to allow insertion of the Gigli guide and saw. Should the dura mater not be separated before the Gigli guide is inserted, there is the danger that the dura may be pierced and the brain damaged. When sawing bone, control of the Gigli saw is best obtained by locking the elbow joints in a flexed position and by restricting movement largely to gentle rotations of the body. Movements at the shoulder joints are kept to a minimum. The hands are kept as wide apart as possible so as to avoid kinking and breaking of the saw. The bone is cut on the bevel from below, upwards and outwards. Bevelling in the correct plane in the first instance eases the lifting of the flap, and at closure ensures that the flap tends naturally to sit and stay in a good position. No attempt should ever be made to raise a bone flap until its base has either been completely severed or so weakened by nibbling or saw cuts that virtually no force is necessary to break it across. As a rule, the attachment between the dura and bone, apart from the points of entering vessels, is so loose that a bone flap when properly cut can be lifted and broken back with little difficulty. Occasionally, and particularly in old people, the dura mater over the frontal zones becomes firmly attached to the bone, and the lifting of a bone flap becomes not only difficult, but hazardous, since the dural membrane may be avulsed and large cerebral vessels torn. In these cases of dural adherence every effort should be made by suitable dissection to clear the dura before attempts are made to lift the bone flap. The various stages in the lifting of a flap and the preparation of the operative field are shown in the following drawings. When closing the wound it is often necessary to remove the jagged edges of the flap with nibblers before it will fit snugly back into position. To secure the bone flap back into position it is usually necessary only to sew together the edges of the cut pericranium. When solid securance is deemed necessary, drill holes are made in the graft and surrounding skull at corresponding points and the two pulled together with sutures of tantalum wire.

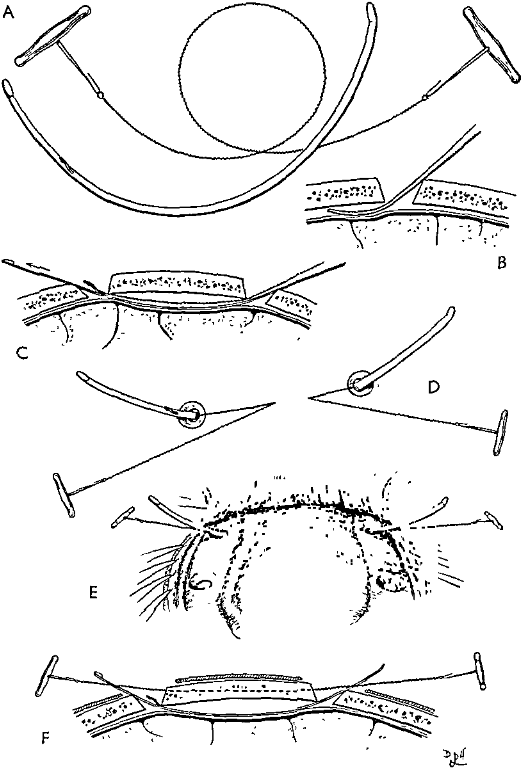


FIG 31

A Gigli saw and guide. B [illegible]
dissector C The Gigli saw [illegible]
D Sawing the bone E, F [illegible]
the overlying muscle.

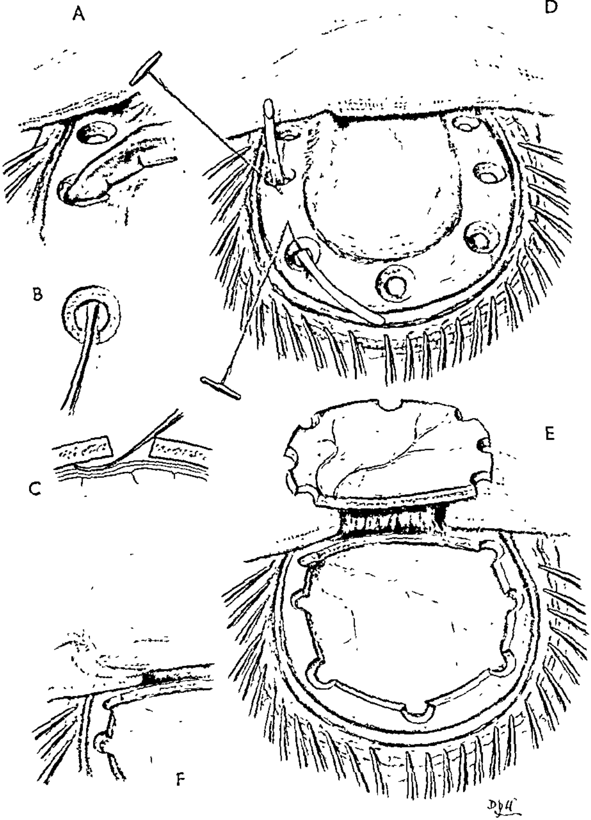


FIG. 33

The Raising of a Bone Flap (2)

A Bleeding from the bone is stemmed by plugging the diplœ with Horsley's wax. B, C. The dura mater is gently pushed from the bone with a curved dissector to ermı [illegible]
D Cutting the bone w h [illegible]

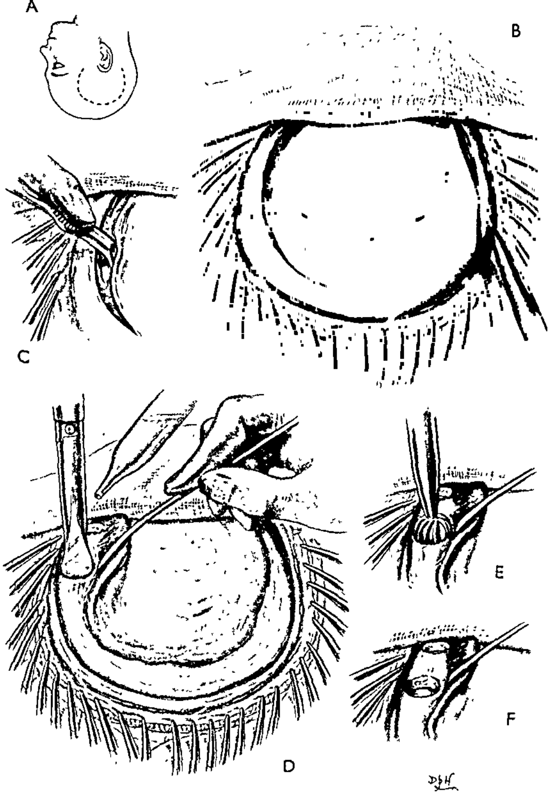


FIG. 32

The Raising of a Bone Flap (1)

A Line of skin incision B A horseshoe-shaped incision is made in the temporal fascia and muscle C. Scraping aside the pericranium with a raspatory D Drilling the skull with a perforator Each hole is washed out with saline immediately after drilling E, F Widening the holes with a large burr

The position of a bone flap must, of course, be determined by the object of the operation: its exact size and shape are conditioned largely by anatomical considerations. As a rule, it is much better to cut a flap considerably larger than is necessary, rather than to run the risk of being left with it too small. Often it is necessary to expose areas beyond the pathological lesion for the ligation of large arteries and veins at the most advantageous anatomical site. For example, when a parasagittal meningioma is being removed, the edge of the superior sagittal sinus must be clearly in view. Also in cortical excisions it is often necessary to expose areas beyond the pathological zone in order to let the operator get his correct anatomical orientations. The anatomical conditions of the head are such that flaps of all shapes and sizes can be taken down in the vault. In the posterior fossa, on the other hand, choice of size and shape of flap is very limited. For cosmetic or for other reasons a skin flap may be of totally different shape than that of its bone flap. In such cases it is necessary first of all to reflect the skin flap before the bone flap can be outlined and cut. When a flap is turned in this way the brain-scalp circulation must be severed twice—the first time when the skin is separated from the bone, and secondly when the bone is lifted from the dura mater. In certain conditions, and particularly in the presence of meningiomata or angiomata, which are highly vascular tumours, and where the brain-scalp circulation is much engorged, it is wiser to restrict the breaking of the brain-scalp circulation to one stage—to the stage when the bone is raised from the dura mater. This single breakage is accomplished by the taking down of a so-called true osteoplastic flap. In this case the scalp is not separated from the surface of the bone save along the actual line of the incision. The disadvantage of this true osteoplastic manœuvre is that in the first stage manipulations are a little obstructed by the cumbersome bunching of artery forceps or hæmostatic clips. Apart from brain-scalp circulation consideration, another advantage of the true osteoplastic flap is that the subgaleal space remains closed and so fluids cannot accumulate superficial to the bone to interfere with healing or to lead to infection. One of the dangers of turning a frontal bone flap is opening into the frontal air sinus with resulting infection and osteomyelitis. Careful pre-operative examination of radiographs of the skull and correct placing of the lower midline will obviate this serious danger. Should the frontal air sinus be unintentionally opened, the hole should be repaired by a fascial graft or whatever means is at one's disposal, and a decision made whether or not it is safe to continue with the operation.

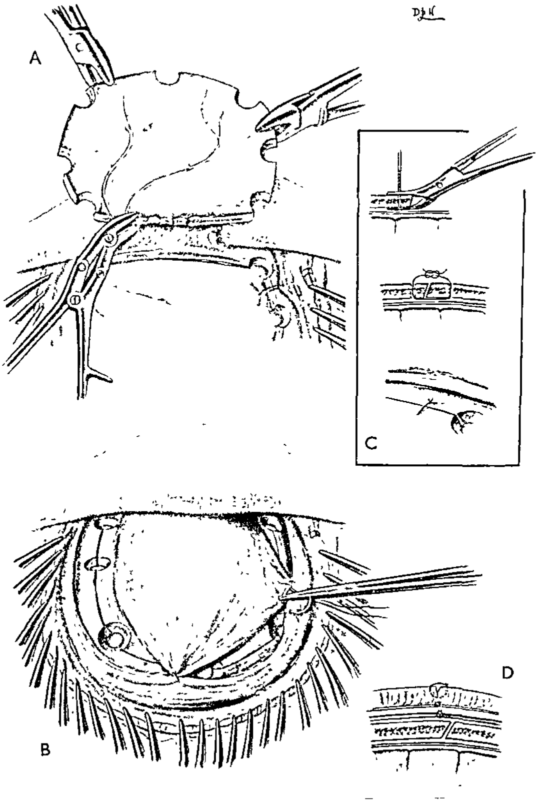


FIG. 34

Closure of a Bone Flap

A To ensure easy replacement of a bone flap, it is often useful to remove a small amount of bone from the lower edge of the flap B Approximation of the temporal fascia and muscle. C Occasionally it is necessary to wire a bone flap firmly back into position D. The layers of closure.

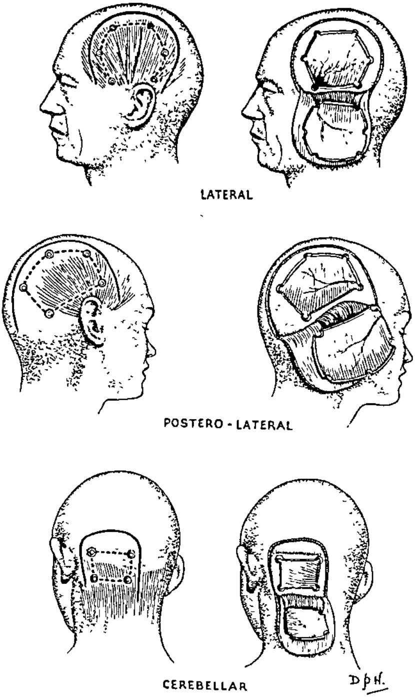


FIG. 36
Routine Bone Flaps (2)

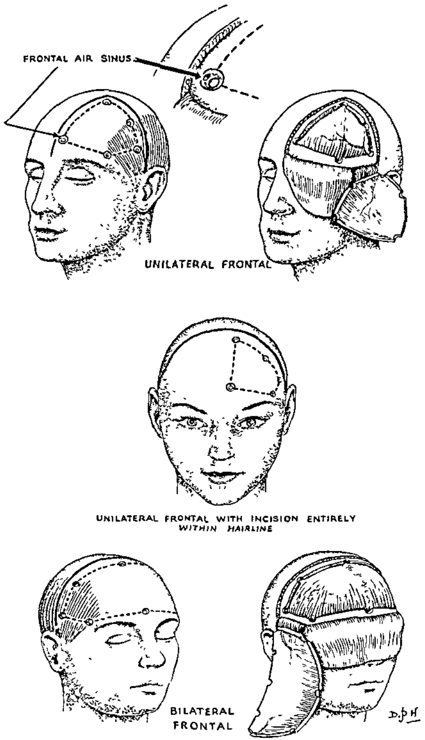


FIG 35

Routine Bone Flaps (1)

CHAPTER IV

SURGERY OF THE BRAIN

ON closure of the scalp at the completion of an operation, it can be taken as an axiom that if a ruptured artery or vein, however small, is left to bleed, the bleeding will continue until the resulting clot has seriously compressed the brain. Therefore complete hæmostasis must be procured before the dura mater is closed and the bone flap replaced. Deep bleeding from the edges of the skin can occur after suture of the scalp, and the blood can collect beneath the bone to form an extradural hæmatoma. To prevent such bleeding, the galeal layer should be firmly apposed by means of buried sutures and the skin stitches placed closely enough to ensure that the larger vessels are occluded.

Intradural bleeding is a serious complication, since the resulting cerebral catastrophes develop rapidly and are difficult to diagnose and cure. Extradural hæmorrhage may take place relatively slowly and so permit of diagnosis and evacuation of the clot. An extradural clot may develop, however, while the patient is still unconscious from an anæsthetic, when the absence of a latent interval makes diagnosis difficult.

To stop bleeding by packing is a dangerous procedure. Heavy pressure on the brain will not only produce bruising but may displace the brain and rupture a tethering vein some distance beyond the limits of the bony exposure (see Fig. 38). Rupture of a large distant vessel may necessitate a new bony opening before the bleeding can be controlled. It is by suction that a bleeding vessel must be exposed for ligature or sealing. Indeed adequate suction is an essential part of neurosurgical technique. Only when every other method of hæmostasis has failed is it permissible to pack. Packing then is best done with muscle or Gelfoam.

The peculiarities of the cerebral circulation lead to considerable technical difficulties in hæmostasis. In particular, the veins on the surface of the brain do not follow the same course as the arteries. Therefore, in resection of the cortex, vessels concerned primarily in the vascularisation of neighbouring areas may encroach on the field of resection and require ligature. An artery may divide at one point into several branches that run into different planes, one to dip deeply into a sulcus. Torn vessels tend to retract into the brain tissue or sulci to add to the difficulties of ligature. The meshwork and toughness of the

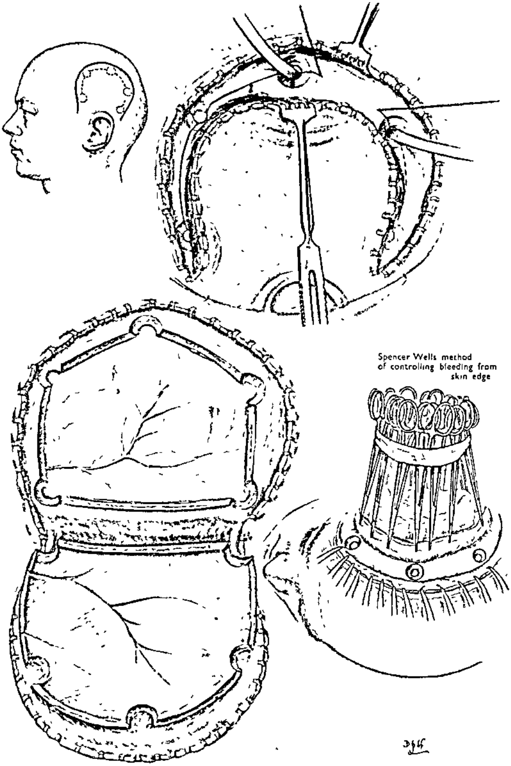


FIG 37

The True Osteoplastic Flap

CHAPTER IV

SURGERY OF THE BRAIN

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leptomeninges may also cause difficulty in the picking up of a torn blood vessel (see Fig. 39). The possibility of infarction and the production of disabilities such as hemiplegia must always be considered before a large artery is ligated. Ligature of a large vein may lead to such severe congestion and swelling of the brain that surgical manipulations become difficult or even impossible.

Apart from correct positioning and skilled anæsthesia, artificially-produced hypotension will, in suitably chosen cases, substantially minimise bleeding and facilitate surgical manipulations.

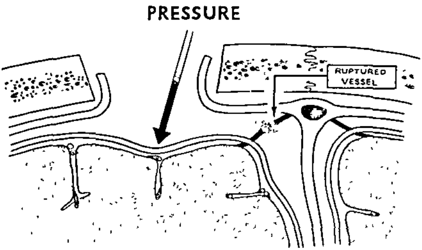

Fig 38

METHODS OF PRODUCING HYPOTENSION

The advantages of operating under the conditions of controlled hypotension are as follows:—

1. The lowered vascular tension reduces bleeding at the site of operation.
2. Diminution of the volume of the circulating blood causes shrinkage of the brain, which facilitates retraction or access to deeper structures.
3. The need for supplies of stored blood is minimised.

The degree of hypotension desirable and safe lies usually somewhere between 80–100 mm. Hg, the precise figure being dependent on such factors as the general state of health of the patient and the height of his blood pressure under normal conditions.

Hypotension may be produced by exsanguination—arteriotomy or venesection—or by chemical block of autonomic ganglia.

Whichever method is chosen, the blood pressure is lowered just before the incision in the scalp is made, and then raised again to a little over 100 mm. Hg just before the dura mater is closed. If the pressure is not raised before the dura mater is closed, serious intradural bleeding may occur post-operatively. Also the blood pressure should be maintained at the decided figure by immediate transfusion should blood loss at any point of the operation be severe.

After the systolic blood pressure has reached 110 mm. Hg the blood is replaced by the usual method of slow drip transfusion. When working at hypotension levels for too long—say over one hour—or below 80 mm. Hg, there is always the serious danger of thrombosis.

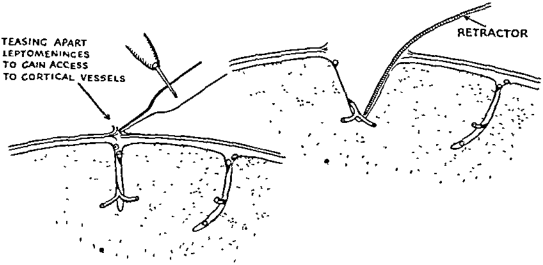

FIG. 39

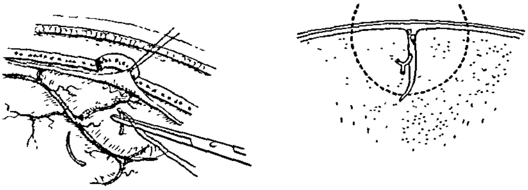

FIG. 40

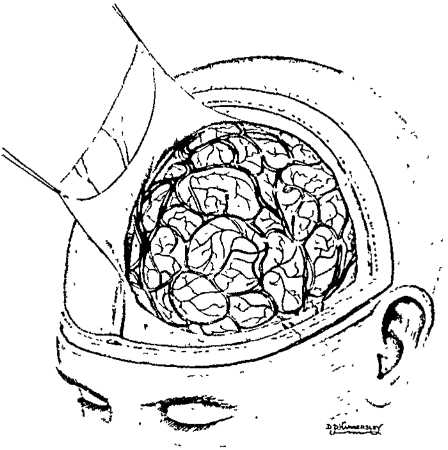

FIG. 41

In this illustration we have attempted to show the cortical circulation as it appears on opening the dural envelope It will be seen that the veins tend to run along the sulci, only occasionally crossing over the gyri, whilst the arteries appear to wander haphazardly over the whole surface of the brain.

If, for example, we follow the course of a cerebral vein from the low temporal region we will see that it
he
of

A cerebral artery, on the other hand, may arise from the Sylvian fissure, run alongside a vein for a short distance throwing out many tortuous branches on either side, and then plunge deeply into a sulcus to reappear crossing a gyrus higher up the hemisphere Finally, it may disappear beneath the meshwork of large veins near the superior sagittal sinus.

The entire vascular system of the surface of the brain is bathed in cerebrospinal fluid, which gives the brain a characteristic lustre particularly noticeable in the wide troughs of the sulci where the cerebrospinal fluid collects in pools The lustre is enhanced by the transparent canopy of the arachnoid covering the large cortical vessels

SURGICAL METHODS OF HÆMOSTASIS

Sealing by Diathermy

A coagulating diathermy current is convenient for the sealing of veins and small arteries in the muscle, dura and brain. A useful method is to pick up the vessel concerned between the blades of a finely-pointed dissector and, as the field is dried with the sucker, to touch the dissector with the diathermy electrode. It is dangerous to use diathermy coagulation for sealing vessels in the scalp itself, since the edges of the skin may necrose and slough, thus preventing primary healing. At those points where the cortical vessels have become deep to the pia mater, this membrane, which is very tough and resistant, has to be pierced on each side before the vessel can satisfactorily be picked up in the jaws of the dissecting forceps.

Diathermy coagulation is a most valuable method of procuring hæmostasis and can be regarded as an essential part of neurosurgical technique. When using the diathermy current, whether for cutting or for sealing, great care must be taken not to touch other instruments, particularly those in contact with the skin.

Compression by Metal Clips

By means of a special holder (Mackenzie's or Cushing forceps) a U-shaped clip, either of silver or tantalum wire, can be flattened to compress an artery or vein. Compression by this means has now become a routine procedure in the procuring of hæmostasis in cerebral surgery. Skill is necessary in the application of the clip, particularly in preventing drag on the vessel. The vessel must, of course, be embraced in the "U" of the clip, and the limbs of the clip must be longer than the diameter of the vessel to be clamped, otherwise the vessel wall will be pierced.

Ligature

An attempt to pick up a cerebral blood vessel in the jaws of a Spencer-Wells forceps almost invariably leads to laceration of the cerebral cortex and to tearing of the vessel itself. The weight of the forceps alone is apt to drag the vessel out of its bed, with resulting rupture of deeply-placed tributaries. On occasions, an artery forceps may be used with advantage to clip together a tear in the edge of a large dural venous sinus until repair by suture can be carried out.

Ligature is a method almost exclusively used in planned excision of the cerebral cortex. The vessels to be divided are underrun with needle and silk thread, the needle being passed deeply so that the danger of piercing deeply-placed branches and nearby veins is minimised (see Fig. 40). As a knot is tied and tightened, great care must be taken not to drag on the vessels. Indeed much practice is necessary before the technique of ligature can be perfected. Veins and arteries may be bunched in one ligature if they happen to run close together in the same direction.

Hæmostasis by Muscle or Gelfoam Grafts

A flat piece of muscle cut, for example, from the temporalis and hammered into a fine sheet will stick to the dura or brain surface like a postage stamp. It is rarely necessary to use this method on the vessels of the brain itself, but it is of particular value in sealing those veins of the dura concerned in the brain-dura-scalp circulation. Gelfoam is a proprietary preparation, and is best applied after it has been soaked in thrombin.

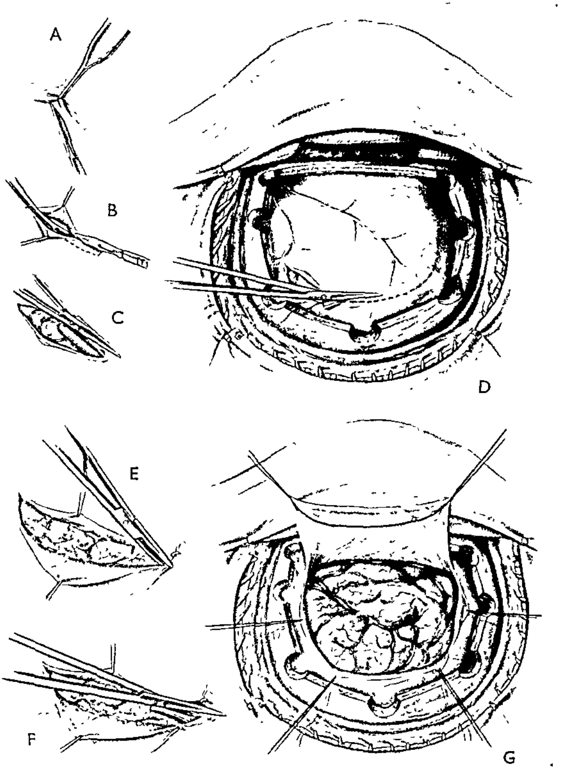

FIG. 42

Opening the Dura Mater

A The start of the incision into the dura mater B. Protection of the cortex of the brain by a metal guide C Protection of the cortex of the brain by a wet sheet of lintine. D. In low temporal flaps, such as this, it matters little whether the dural flap is turned down or up: in this case it was turned down E The application of small silver clips. F The division of a vessel between silver clips. G. Exposure of the brain surface.

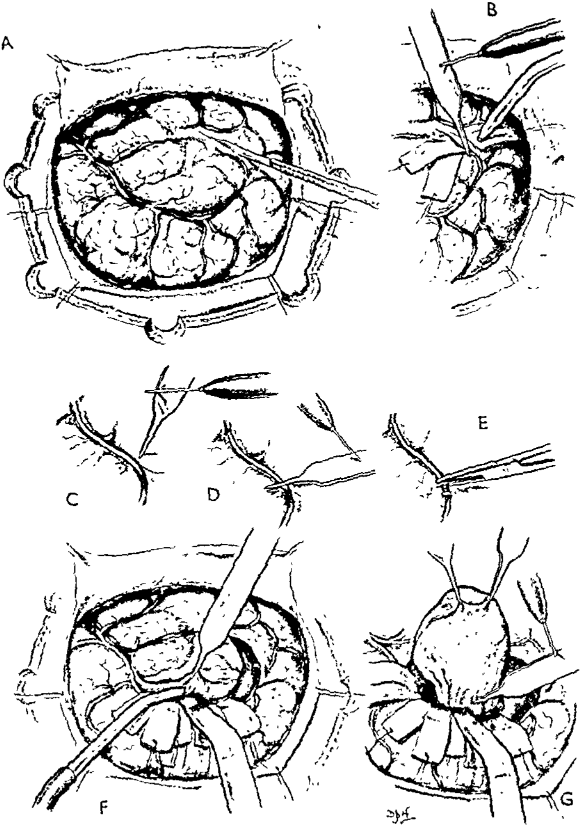

FIG. 43

Cortical Manipulations

A Incision into a *relatively* avascular part of the cortex. B. *Sealing* vessels by diathermy after the cortex has been excised by scalpel C, D Special method of sealing a vessel by diathermy Holes are first made on each side of the vessel through the tough pial membrane The vessel is then grasped between the jaws of dissecting forceps and the diathermy current applied. E. Sealing with silver cli s F. Dissection by suction G Diss o with for

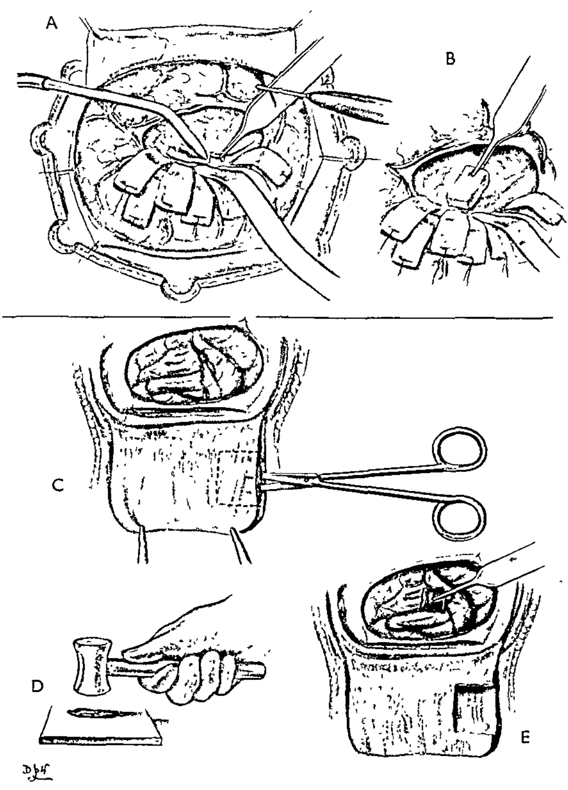

FIG. 44

Methods of Hæmostasis

A Sealing by diathermy coagulation B Hæmostasis by stamps of Gelfoam C, D, E Hæmostasis by muscle grafting.

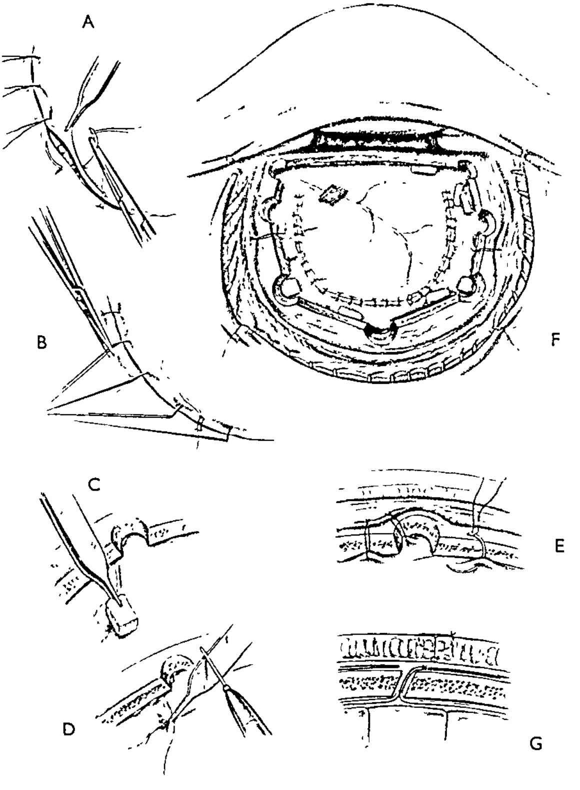

Fig. 45

Closure of the Dura Mater

A Apposition of [illegible]

[illegible] used, they are cut as close to [illegible] ermy coagulation. E. Hitch- [illegible] mplete hæmostasis obtained.

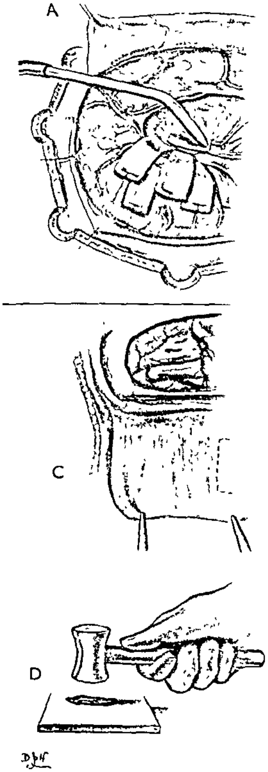

FIG. 44

Methods « 'emostasis

A Sealing by diathermy coagulation. B Hæm « by stamps of by mu ·lting

EXTRADURAL HÆMORRHAGES

Extradural hæmorrhages, large enough to be of surgical significance, are found in 2 to 3 per cent of cases in any large series of acute cerebral trauma. Though rare, they are of course extremely important. The bleeding may come not only from the middle meningeal vessels, but also from the diploic veins or dural venous sinuses.

Sinus Bleeding

Tears in the walls of the dural venous sinuses are nearly always associated with overlying fractures. Fortunately they are rare, and this is due no doubt to the fact that the large dural channels, with the exception of the descending limbs of the lateral sinuses, are not embedded in deep bony grooves but run in contact with the flat surfaces of the skull and so are not necessarily lacerated when the overlying bone is fractured. As the sinus walls are fibrous and rigid, they do not collapse or contract when torn as arteries do, with the result that bleeding is often profuse in spite of low venous pressure, and may be so rapid that the extravasated blood has not time to clot before the patient succumbs. Bleeding, however, is not invariably fatal, because the spicule of bone which lacerates the sinus may plug the opening into it or, as occasionally happens, the hæmorrhage may be limited by an adherent dura. Intrasinus pressure, normally low, is greatly increased by the slightest obstruction to respiration, or by compression of the veins of the neck by tight clothing or bandaging. Any increase in venous pressure results in commensurate increase in bleeding.

Usually a tear takes the form of a small triangular flap and less commonly of a transverse or longitudinal split. Complete transections occasionally happen in open wounds, but in closed head injuries they are almost unknown, and in both cases are invariably fatal.

In view of the frequency with which basal fractures converge on the pituitary fossa, injuries of the cavernous sinus are surprisingly rare, the superior longitudinal and lateral sinuses being those most commonly affected.

Diploic Bleeding

Probably diploic bleeding is the most frequent cause of extradural hæmorrhage. Often not more than a thin layer of blood collects; as this does not cause symptoms of cerebral compression, it passes unrecognised and is absorbed by natural processes. Profuse diploic bleeding usually comes from numerous and widespread points, the precise localisation of which is impossible on clinical grounds, since neurological signs point to the position of the clot or accumulation of blood and not to the origin of the bleeding, which may be, and often is, some distance away. Radiology certainly shows the position and length of fracture lines from which the bleeding may emanate, but as these are often multiple and extensive, X-rays can rarely give information of more than lateralising value. The main difficulty in treatment is that the bleeding points may not be accessible through the exposure necessary for the evacuation of the clot or pool of blood which is compressing the brain.

Chapter V

SURGICAL TREATMENT OF INJURIES OF THE HEAD

A PATIENT who has received an injury to his head may, and often does, suffer from more than concussion or commotio cerebri. He may, for example, develop a massive surface hæmorrhage that can only be localised and treated by surgical means. He may fracture his ethmoidal sinus and lacerate the overlying dura mater and run the danger of *developing septic meningitis; such injuries are known as internal compounding and may* necessitate surgical intervention.

As a result of road accidents, it is common for a man to lacerate or tear his scalp so severely that major surgery is necessary.

Compound fractures of the vault must be carefully and skilfully excised if primary healing is to be obtained and complications minimised.

Rises of intracranial pressure have occasionally to be treated by decompression.

Sequels of head injuries, for example defects of the skull, often call for surgical repair.

It is not, however, our intention to imply that surgery has a particularly large part to play in the treatment of acute injuries of the head; on the other hand, the part that it does play is exceedingly important and often difficult.

Therefore we have decided to illustrate the more common of the surgical procedures that are used in the Head Injury Centre of Region 1.

Every operation, however minor, must be adequately planned and carefully executed. Any kind of carelessness may easily vitiate what otherwise would have been a good result. For example, imperfect apposition of the skin may lead to faulty healing and to infection of deeper structures and osteomyelitis or cerebral abscess. Also, the surgeon must always be prepared to carry out a much more extensive operation than he originally anticipated. Careful pre-operative assessment of a case is most important, since there is nothing more disturbing than to find that one is dealing with a much more serious lesion than at first was thought present

We shall take it for granted that the principles of surgery are to be observed in all their phases For example, we shall start on the assumption that shock has already been combated and that blood transfusions, if necessary, have already been given.

Finally, we should like to emphasise that our suggestions for positioning and towelling of the patient that have been illustrated in earlier chapters, along with theatre technique, apply equally to the surgery of injuries of the head as to the surgery of cerebral tumours.

important to remember that they also occur at any site within the skull from the posterior to the frontal fossa, and may be parasagittal or basal in position.

Types—

1. They may be unilateral and uncomplicated.
2. They may be bilateral.
3. They may be associated with subdural bleeding.
4. They may be associated with intrinsic damage to the brain (neuronal injury).
5. They may be associated with subdural bleeding and neuronal injury.

Diagnosis on Clinical Criteria

Group 1 consists of those patients who are unconscious when first seen but who have been conscious during some period after the accident. The latent interval is usually a number of hours but may be as long as a week or two. The first symptom is increasing headache, and this must never be treated lightly when a history of an injury, however slight, has been given. Giddiness, mental confusion or drowsiness must be regarded as pathognomonic and not merely as suspicious signs of extradural compression. As the hæmorrhage increases, drowsiness or confusion changes to unconsciousness, and signs of pyramidal impairment develop on the opposite side of the body. At first the limbs become weak and spastic. Convulsive twitchings may occur at any stage either early or late The reflexes are typical of those of an upper motor neurone lesion; the knee jerk is increased, the abdominal reflexes on the same side are diminished or absent, and there is an extensor plantar response. Respiration, at first fast and deep, slows and then becomes irregular. The pulse in a fully developed case is slow, *i.e.* below sixty beats a minute, and the blood pressure is high. A fixed dilated pupil may or may not be present, and in any case is usually a late sign.

When pyramidal signs are confined to one side of the body, lateralisation of the hæmorrhage is easy, but if the clot is not evacuated at this stage, bilateral motor signs rapidly appear and diagnosis is much more difficult. Often a patient is first seen when bilateral signs are well developed. In these cases there may be (1) bilateral spasticity, (2) spasticity on one side and flaccidity on the other, or (3) bilateral flaccidity. These possible combinations are explained by the way the clot compresses the brain. First the cortex on the side of the hæmorrhage is irritated, and this may lead to convulsive seizures in the contralateral limbs. Then venous congestion develops at the site of compression and causes a spastic type of paralysis. Later the cortex becomes ischæmic and a spastic changes to a flaccid paralysis. Finally, as the clot expands, a similar sequence of phenomena occurs on the opposite side of the brain, and the combination of clinical signs found at any time depends on the phase of compression.

Middle Meningeal Hæmorrhage

The middle meningeal artery arises from the internal maxillary branch of the external carotid artery, and enters the middle fossa through the foramen spinosum which lies just behind and lateral to the third division of the trigeminal nerve. Throughout its intracranial course it is accompanied by two venæ comites, which means that whenever the meningeal vessels are ruptured, bleeding takes place from both ends. From the foramen spinosum the artery runs forwards and outwards on the base of the skull towards the tip of the great wing of the sphenoid bone, where it divides into an anterior and posterior branch The anterior branch continues upwards and forwards to the antero-inferior angle of the parietal bone, which it deeply grooves or tunnels, and then turns upwards and backwards towards the vertex. The posterior branch runs backwards and upwards across the squama of the temporal bone to the occipital region, this being the branch most commonly exposed in temporal decompressions.

A point of interest is that the grooves in the bone caused by the anterior branches are commonly visible in X-rays and may be confused with fracture lines. Apart from its named branches, which are of little surgical importance, numerous small twigs run into the bone, and are very easily avulsed whenever the dura moves away from the bone as the skull is deformed. Inosculations across the middle lines between the vessels of either side are not very free, but they are widespread between the anterior and posterior branches on each side.

The vessels may be ruptured in many ways: they may be transfixed by a spicule of bone, or lacerated by the edge of a fracture or torn by stretching. Bleeding may not take place immediately the vessels are torn, owing to the influences of shock, but as the circulation recovers and the blood pressure rises, rapid and profuse bleeding may occur. The latent interval which so commonly occurs in middle meningeal hæmorrhages is not always due to shock, but often can be accounted for by the ability of the brain to accommodate itself to a slowly expanding lesion for a long time before showing signs of compression. In many cases the vessel bleeds from the moment the injury is inflicted, but often at a slow rate, due partly to incomplete rupture and partly to the resistance of the dura to stripping Immediate prodromal symptoms such as headache are the rule rather than the exception, and the rapid development of neurological signs later indicates loss of compensation in the brain rather than a sudden severe hæmorrhage. Clots usually take the form of a segment of a sphere, the summit of which corresponds with the bleeding point on the dura, and they may be found in any position within the skull.

Sites of Occurrence

Though the majority of extradural hæmatomata arise as the result of rupture of the middle meningeal vessels and collect over and under the temporal lobe of the brain, it is

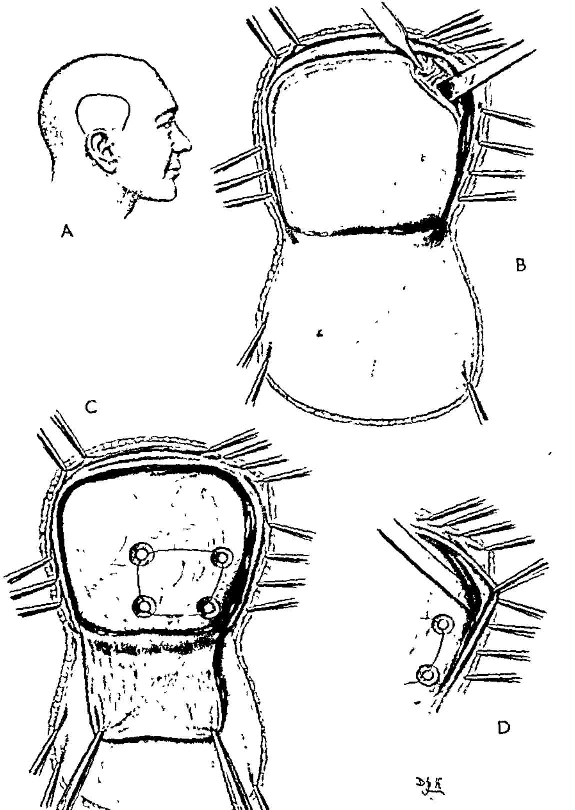

FIG 46

Subtemporal Decompression by Muscle Slide

A Line of skin incision B Subperiosteal separation of the temporal fascia from the bone. C Proposed area of bone removal in the first instance. D. Mobilisation of the anterior and attached part of the temporal muscle to permit of removal of the bone overlying the tip of the temporal lobe of the brain.

In a combination of flaccid and spastic paralysis the clot, therefore, is on the side of the brain opposite to the limbs showing signs of flaccid paralysis. In cases in which there is no difference between the two sides of the body, lateralisation of the clot on physical signs alone is impossible, but the diagnosis may be made if the sequence of events is known.

Group 2 consists of those patients who are unconscious when first seen and who have not been conscious at any time since the accident. The possibility of clot is particularly raised by retrogression following a period of improvement that cannot be controlled by spinal drainage.

Diagnosis by Means of Inspection Holes

Local exploration through burr or trephine holes has substantially helped to solve the problem of the diagnosis of extradural hæmorrhage. In any case, when diagnosis is in doubt a local exploration should always be made. Provided that the exploration is made under local anæsthesia and with neurosurgical precautions, no harm is done to the patient even if the findings do not lead to further useful operative procedure.

Site of Operation and Surgical Procedure

The inspection hole is placed according to the neurological evidence or to the presence of fracture lines or bruising. When made in the classical position about the pterion, the skin incision should be made vertically, so that if a hæmatoma is found, the incision can be curved upwards and backwards to fashion a formal subtemporal exploration. When made elsewhere, over a fracture or sprung suture line, the skin incision should be so [illegible]

[illegible]

and a decision has been made to operate, at least four holes on each side of the head at the points indicated in Fig. 74 must be made before the diagnosis is abandoned. An atypically-sited extradural hæmorrhage can be most difficult to locate. The advantage of a trephine hole over a burr hole is that the disc of bone may be replaced and the skull thus repaired if drainage at a particular site is not found necessary.

The Management of Extradural Hæmorrhage

Middle Meningeal Hæmorrhage

After confirmation of the diagnosis has been made through an inspection hole, the clot is exposed either by means of a subtemporal muscle split or muscle slide decompression (Figs. 46, 47, 48, 49, 50) When once the bone has been removed it is wise to wait for a few minutes to allow the cerebral circulation to readjust itself to the new conditions. It is extremely dangerous to insert a finger into the wound in an endeavour to hook out the clot, as troublesome bleeding may be induced before one is in a position to control it. Moreover, the extra pressure of the finger superimposed on the already existing compression of the clot may prove fatal. The clot should be removed slowly a little at a time from above downwards with a suitable instrument, such as a teaspoon or a curved dissector, until the ruptured meningeal vessels come into view. The bleeding vessels are most easily sealed

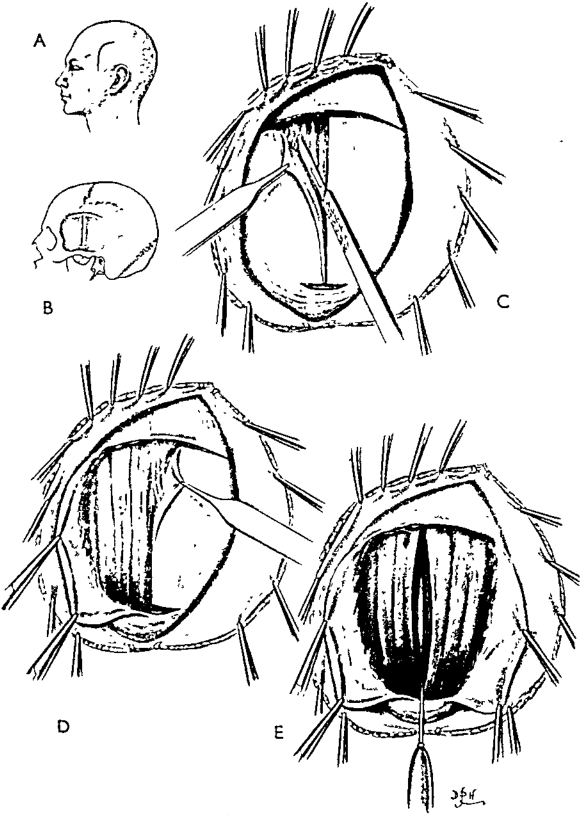

FIG. 48

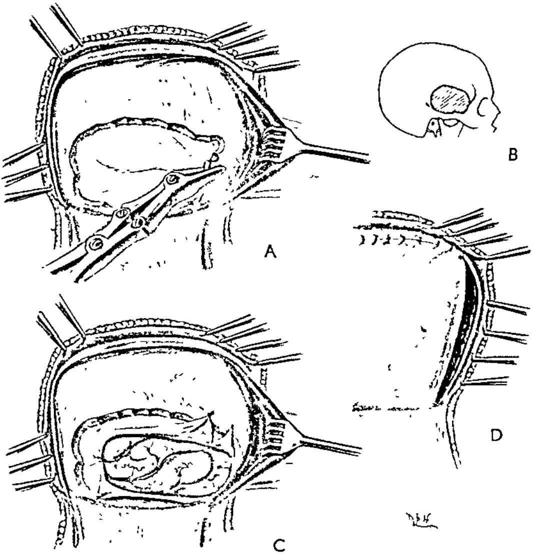

FIG. 47

Subtemporal Decompression by Muscle Slide

A The exposure of the extradural space. B Site of bony entrance shown on the skull C The decompression completed The dura is sutured to the pericranium to prevent formation of post-operative clots D. The fascia is sutured above and behind. Anteriorly the fascia is left open—here only the muscle fibres are pulled together.

FIG. 48

Subtemporal Exploration by Muscle Split

A Line of incision in skin B Line of incision in temporal fascia C, D. Method of reflecting temporal fascia E. Splitting of muscle vertically

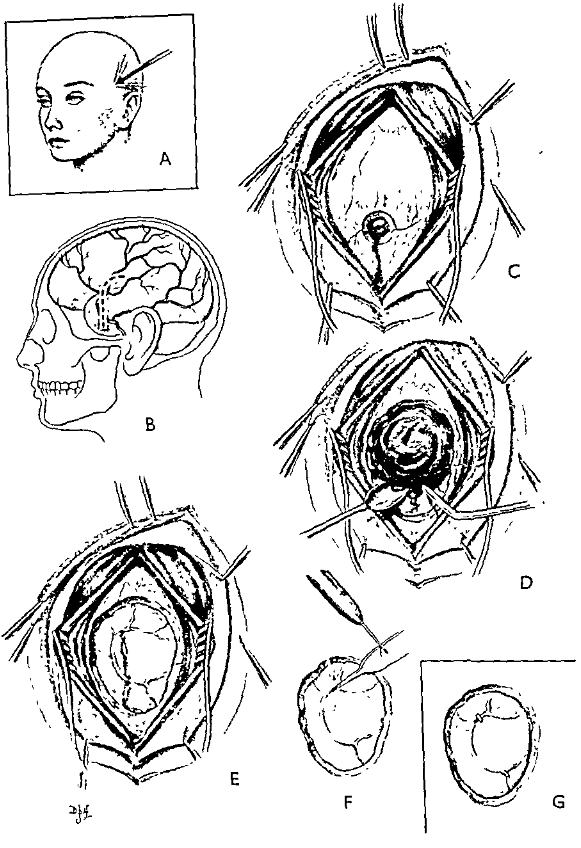

Fig. 50

The Management of an Extradural Hæmatoma due to Rupture of the Middle Meningeal Artery

A. The site of application of the blow. B T[illegible]
C Exposure of the temporal fossa by the mu[illegible]
extradural clot. D The clot is uncovered [illegible]
F. Sealing the ruptured vessel by diathermy [illegible]

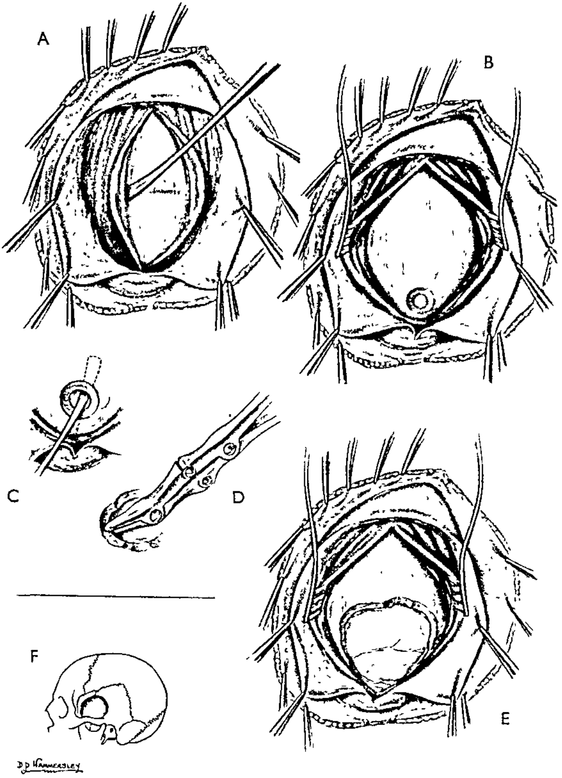

Fig. 49

Subtemporal Exploration by Muscle Split

A. Separation of muscle from bone B Exposure of bone C Separation of dura with curved dissector D Removal of bone by nibbling E. Exposure of the extradural space. F. The opening in terms of the skull, it is a common fault to place an opening too high and too far back.

there is no sign of return of consciousness within a quarter of an hour, the dura mater is widely opened and a formal subtemporal decompression provided. If half an hour after the decompression has been made there is still no sign of return of consciousness, the temporal lobe of the brain should be lifted and the edge of the tentorium severed to relieve possible tentorial herniation. It is profitless to close a wound until there is evidence of returning consciousness.

EXTRADURAL HÆMATOMATA IN ATYPICAL POSITIONS

Though it is occasionally possible to diagnose the precise position of an atypically-placed extradural clot on neurological grounds, it is, in actual practice, rare to be able more than to lateralise it. Severe and deep scalp bruising or a scalp wound may point to the position of the clot, as will the radiographic evidence of a fracture line crossing, for example, the lateral sinus. Such evidence, however, is often absent or can be misleading. Positive evidence by electroencephalography or by cerebral angiography of a dead area is, of course, invaluable, but we fully realise that facilities for these special investigations are not yet at the command of every clinic dealing with cerebral trauma. In any case, diagnosis finally has to be confirmed by direct inspection, and simple burr holes under local anæsthesia are much less dangerous than angiography.

We must emphasise how difficult it can be to localise an atypically-placed extradural hæmatoma, and how easy it is to overlook even a large clot if sufficient burr holes are not made. When once the hæmatoma has been discovered, the object of the next stage of the operation is to uncover it widely. This uncovering may be done by raising a flap or by nibbling away the bone in whichever direction the clot leads. Piecemeal nibbling of the bone is the usual method employed for opening up the wound, because even when the clot has been seen through a burr hole its distribution cannot be judged with precision. By the time a clot has been widely uncovered, the bleeding point has usually been exposed or brought within surgical reach. In removal of the clot the same precautions are necessary as described in cases of middle meningeal hæmorrhage. Light packing of the wound is sometimes necessary to control bleeding. Also, it is quite permissible to leave part of the wound open for later suture until the patient has reached, or is well on the way back to, consciousness.

The following is an account of the details and difficulties encountered in the management of a case of atypically-placed hæmatoma (Figs. 52, 53).

On 26.11.52, at 12.10 p.m., a doctor colleague of one of us (G. F. R.), whilst working in his dispensary, was struck on the top of the head by a falling jar and was knocked to the floor unconscious. As far as can be judged, he remained in this condition for a few minutes and then walked to the first-aid room of the factory in which he was employed. On examination of his head, a cleanly incised wound about ¾ inch long was found in the right

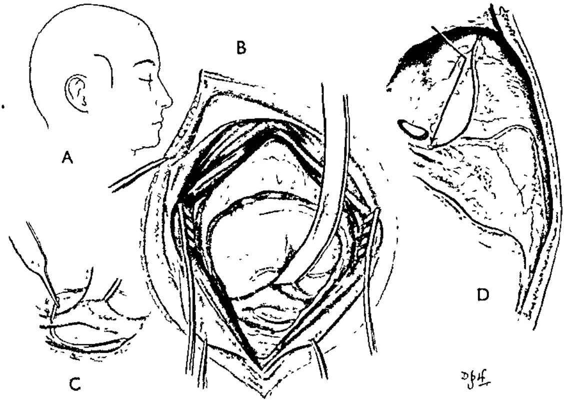

FIG 51

A Method of Plugging the Foramen Spinosum following Rupture of the Middle Meningeal *Artery at the Base of the Skull*

A. Line of skin incision for the muscle split operation B. Exposure of the foramen spinosum by lifting the temporal lobe with a flat brain retractor. C. Inserting a wedge of matchstick into the foramen spinosum D. The bony anatomy surrounding the foramen spinosum. (The arrow shows the site of the foramen spinosum)

with the coagulating diathermy current, but if this is not available they may be underrun with a fine suture and ligatured or compressed with a silver clip. The vessels rupture usually at a point above the base of the skull and are easily accessible. Rupture on the base of the skull is much less common, and the necessity of plugging the foramen spinosum with a wedge of matchstick or with bone wax to stop bleeding is fortunately rare (Fig. 51). To do this successfully an efficient headlight is essential, and the temporal lobe must be raised with flat brain retractors.

WHEN TO OPEN THE DURA MATER

Here we are assuming that the operation has been carried out under local anæsthesia, and that the extradural clot has been cleanly and gently evacuated and that bleeding vessels have been firmly sealed The operation is then halted until signs of recovery of consciousness are obvious. When this stage is reached, the wound is closed in the usual way. If

there is no sign of return of consciousness within a quarter of an hour, the dura mater is widely opened and a formal subtemporal decompression provided. If half an hour after the decompression has been made there is still no sign of return of consciousness, the temporal lobe of the brain should be lifted and the edge of the tentorium severed to relieve possible tentorial herniation. It is profitless to close a wound until there is evidence of returning consciousness.

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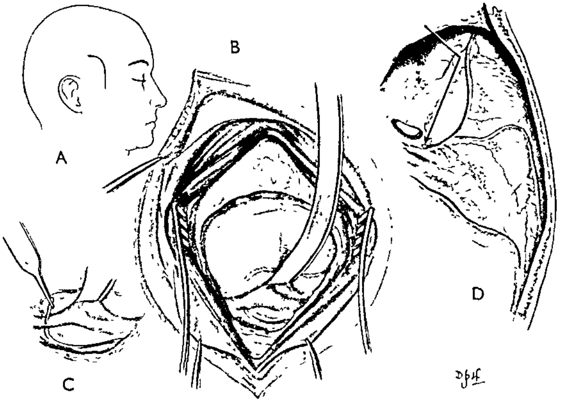

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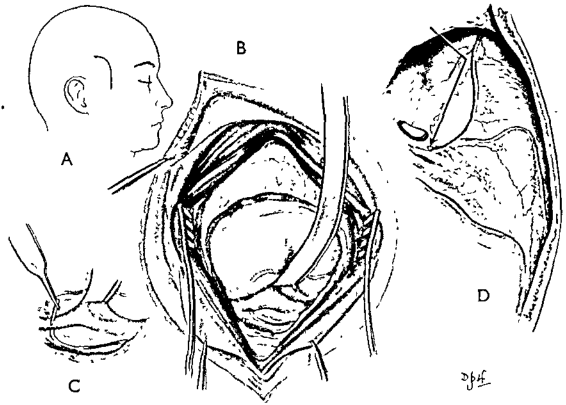

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A Method of Plugging the Foramen Spinosum following Rupture of the Middle Meningeal Artery at the Base of the Skull

A Line of skin incision for the muscle split operation B. Exposure of the foramen spinosum by lifting the temporal lobe with a flat brain retractor C Inserting a wedge of matchstick into the foramen spinosum D The bony anatomy surrounding the foramen spinosum (The arrow shows the site of the foramen spinosum)

with the coagulating diathermy current, but if this is not available they may be underrun with a fine suture and ligatured or compressed with a silver clip. The vessels rupture usually at a point above the base of the skull and are easily accessible. Rupture on the base of the skull is much less common, and the necessity of plugging the foramen spinosum with a wedge of matchstick or with bone wax to stop bleeding is fortunately rare (Fig. 51). To do this successfully an efficient headlight is essential, and the temporal lobe must be raised with flat brain retractors.

WHEN TO OPEN THE DURA MATER

Here we are assuming that the operation has been carried out under local anæsthesia, and that the extradural clot has been cleanly and gently evacuated and that bleeding vessels have been firmly sealed. The operation is then halted until signs of recovery of consciousness are obvious. When this stage is reached, the wound is closed in the usual way. If

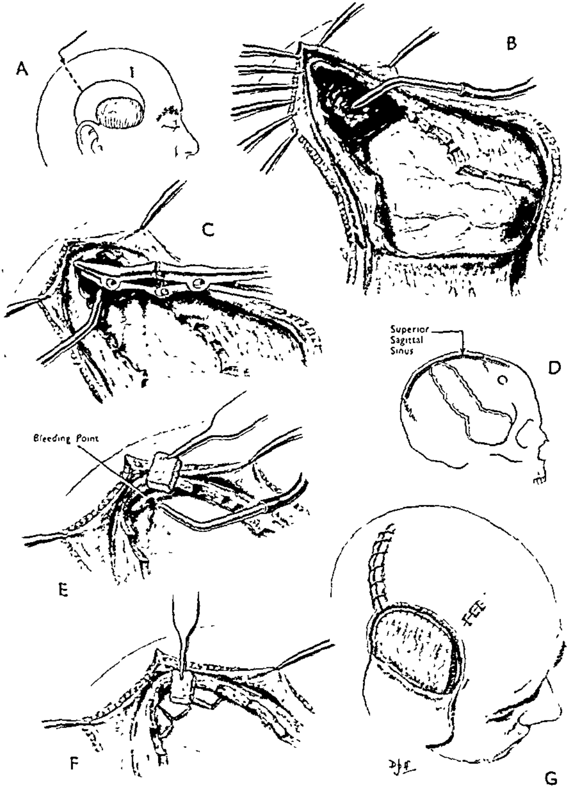


FIG. 53

The Diagnosis and Management of an Atypically-placed Extradural Hæmatoma (2)

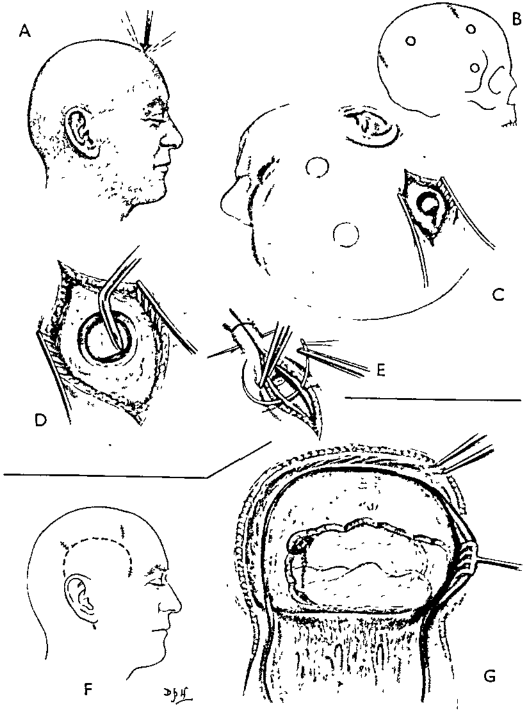


FIG 52

The Diagnosis and Management of an Atypically-placed Extradural Hæmatoma (1)

First Operation —A Direction and site of application of the blow. B. The sites at which inspection holes were made C The location of the clot D Local drainage of the clot. E. Reformation of the wound

Second Operation —F The line of incision of the subtemporal decompression. The original inspection hole wounds are shown feathered with the stitches G. The subtemporal exploration by the muscle slide method.

In view of the history of injury and the findings at the first operation, it was decided to reopen the head more extensively. The operation was carried out under local anæsthesia.

Since there was evidence of a tentorial pressure cone, it was decided to relieve intradural pressure forthwith by a subtemporal decompression. A muscle-slide subtemporal exploration was rapidly carried out, and the tail of the extradural clot was seen at the postero-superior periphery of the wound. By means of piecemeal nibbling the clot was followed and uncovered, and the bleeding point in the sagittal sinus exposed. The clot was gently removed by suction and the hole in the sinus repaired with pledgets of Gelfoam. By this time the doctor was recovering consciousness and the dilated pupil had contracted. In view of this improvement, the dura mater in the temporal region was not opened. The area of the repaired sinus was lightly packed with gauze and the wound left open in part of its length. Before the patient had left the operating theatre he was obviously well on the way to recovery. The clot was a large one—several inches wide in each direction and at least one inch in depth. The gauze was removed the following day and the remainder of the wound sutured.

Within a few days the patient was normal, and in fourteen days he was sent to the rehabilitation centre before being allowed to return home. Had this patient been operated on under general anæsthesia we believe he would have succumbed.

anteroparietal region, just to the side of the middle line and forward about the level of the coronal suture of the skull. The wound was pulled together by a single suture. The doctor carried on with his work during the afternoon; on his return home he could not remember having seen his patients and complained of frontal headache. The following morning he felt much better and drove his car to work, a distance of about sixteen miles. He drove home again at midday, and on his arrival complained of severe headache and gradually became drowsy. His general practitioner saw him at 3 p.m. and diagnosed an intracranial bleeding. He was admitted to the Neurosurgical Unit at 6 p.m. on that day, 27.11.52, and at this time his condition was as follows:—

He was drowsy and confused, but could be easily roused, when he was able to co-operate. He complained of very severe headache and asked to be left alone to sleep. There was a sutured wound on the scalp in the position described above. The Babinski response on the left side was extensor; the pupils were equal; there was no squint and the eyes moved co-ordinately. The pulse rate was 76; the blood pressure 120/90; respiration rate 20; temperature 97°. A diagnosis of an extradural hæmorrhage was made on the history of injury associated with a latent interval. The clot was judged to be on the right side because of the pyramidal signs on the left side, and it was judged to be high and anteriorly placed since the site of the wound suggested a possible tear in the sagittal sinus.

Under local anæsthesia the wound on the scalp was opened and a burr hole made; no extradural clot was encountered. The dura mater was incised and a few drops of yellow-tinged fluid escaped under pressure. A second burr hole was sunk at the point of the pterion; no extradural clot was encountered here. A third burr hole was sunk about the parietal eminence; here, the tail of an extradural clot was discovered. By means of a curved dissector a little of the clot was released. Within a few minutes the patient had become fully co-operative although rather loquacious. He stated that his head pains were much relieved and he asked for a cup of tea. There was so much improvement at this stage that it was judged no further surgical procedure was necessary. On return to the ward the doctor was fully conscious, and he spoke intelligently to the nurse who was taking his pulse Twenty minutes later the nurse (Nurse Edna Boyd of the Newcastle-upon-Tyne General Hospital) was called to the telephone, and on her return to his bedside within a few minutes she found the doctor unconscious. The House Physician, who was informed at once, discovered the patient to be unconscious, with a fixed dilated pupil on the right side, and with obvious pyramidal signs on the left side of the body.

At this stage it was difficult to decide whether we were dealing with an increase in the extradural hæmorrhage, with a subarachnoid hæmorrhage, or with epilepsy. A lumbar puncture was not performed to detect a possible subarachnoid hæmorrhage, because if the diagnosis was proved to be incorrect, which in fact it was, there would have been great danger of producing a fatal tentorial cone.

In view of the history of injury and the findings at the first operation, it was decided to reopen the head more extensively. The operation was carried out under local anæsthesia.

Since there was evidence of a tentorial pressure cone, it was decided to relieve intradural pressure forthwith by a subtemporal decompression. A muscle-slide subtemporal exploration was rapidly carried out, and the tail of the extradural clot was seen at the postero-superior periphery of the wound. By means of piecemeal nibbling the clot was followed and uncovered, and the bleeding point in the sagittal sinus exposed. The clot was gently removed by suction and the hole in the sinus repaired with pledgets of Gelfoam. By this time the doctor was recovering consciousness and the dilated pupil had contracted. In view of this improvement, the dura mater in the temporal region was not opened. The area of the repaired sinus was lightly packed with gauze and the wound left open in part of its length. Before the patient had left the operating theatre he was obviously well on the way to recovery. The clot was a large one—several inches wide in each direction and at least one inch in depth. The gauze was removed the following day and the remainder of the wound sutured.

Within a few days the patient was normal, and in fourteen days he was sent to the rehabilitation centre before being allowed to return home. Had this patient been operated on under general anæsthesia we believe he would have succumbed.

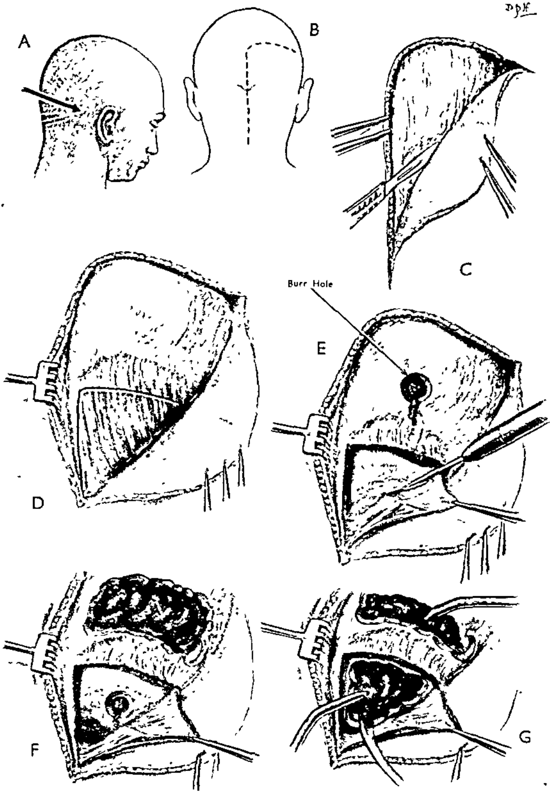


FIG 54

The Management of an Extradural Hæmatoma Straddling the Right Lateral Sinus (1)

A Direction and site of application of the blow B The skin incision C Reflection of the skin flap D Exposure of the nuchal muscle group E Exploratory burr hole in the occipital fossa. Local reflection of the nuchal muscle group F. Burr hole exposure of extension of the clot into the posterior fossa G Exposure of the clot. A remaining bridge of bone covers the lateral sinus

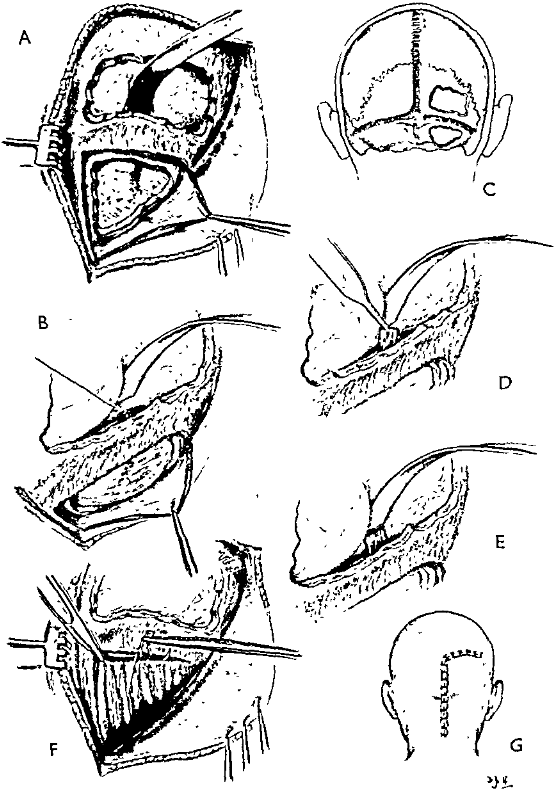


Fig. 55

The Management of an Extradural Hæmatoma Straddling the Right Lateral Sinus (2)

A, B. Exposure of a tear in the lateral sinus. C The relationship of the bony removal to the lateral sinus. D, E Repair of the sinus. F Reformation of the nuchal muscle group. G. Repair of the skin.

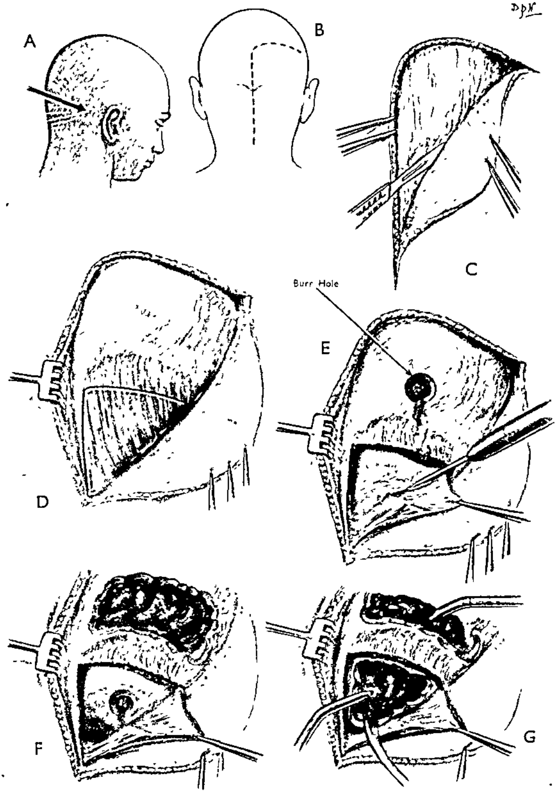


FIG. 54

The Management of an Extradural Hæmatoma Straddling the Right Lateral Sinus (1)

A. Direction and site of application of the blow. B. The skin incision C. Reflection of the skin flap D. Exposure of the nuchal muscle group E Exploratory burr hole in the occipital fossa Local reflection of the nuchal muscle group F Burr hole exposure of extension of the clot into the posterior fossa G Exposure of the clot A remaining bridge of bone covers the lateral sinus.

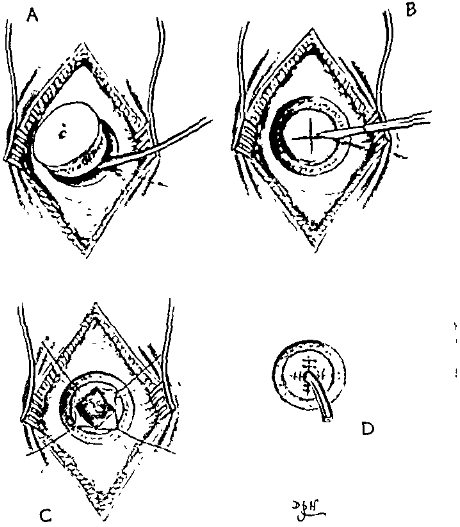


FIG 56

Inspection Holes

A. Lifting of trephine disc. B Opening of dura mater. C. Exposure of a clot D Drainage of subdural or subarachnoid space.

SUBDURAL SUBARACHNOID COLLECTIONS AND BRAIN SWELLINGS

As stated above, local exploration through burr or trephine holes has helped substantially in the solution of the problem of deepening unconsciousness resulting from increasing surface hæmorrhage. On those occasions when an extradural hæmorrhage has been suspected and not found on local inspection, it will be necessary to explore both the subdural and subarachnoid spaces. At each hole when a negative extradural exploration is made, the dura is opened in a cruciate manner (see Fig. 56, B), care in the first place being taken not to open the arachnoid mater. In acute subdural hæmorrhage it is well to remember the blood tends to trickle to the most dependent parts of the subdural sac, and so varies according to the position in which the head is nursed. When a subdural hæmorrhage is found, one of two procedures is possible:

1. The hæmorrhage is aspirated as completely as possible by means of a sucker with a curved end and the cavity drained with a tube for forty-eight hours. No attempt is made to find the bleeding point, as it rarely lies beneath the local exposure. Sealing of the ruptured vessel is left to natural processes.
2. A wide osteoplastic flap is turned, or a subtemporal decompression made, in order to facilitate more adequate removal of the extravasated blood which is often extensive; also, wide exposure permits of search for the bleeding vessel, which, if found, can be sealed by one of the methods described in Chapter IV. *This radical procedure is rarely indicated, and in my opinion should only be carried out when a definite laceration of the brain is seen through the local exposure, or in the case of a large gelatinous clot.* As a general rule it can be laid down that in an acute head injury the simpler the operation the greater are the chances of recovery.

When, on exploration, the subdural space is also found to be empty, the arachnoid mater is incised. If yellowish and bloodstained fluid spurts into the wound, a skull draining tube is inserted and the C.S.F. space drained for one or two days. When on opening the arachnoid mater little subarachnoid bleeding is found and the brain bulges into the wound, we are dealing with brain swelling due either to œdema or to intracerebral hæmorrhage. In these instances one is confronted with the difficult decision whether or not to relieve the intradural pressure by means of a formal subtemporal decompression. When intracerebral pressures are obviously high decompression is indicated.

Indented Fractures

Indentations may be pointed or rounded. They occur chiefly in children when the bones are thin and plastic and often are not associated with a demonstrable fracture line. At birth, particularly following a forceps delivery, rounded and large indentations are often seen in the skull. Most of these disappear within the first few weeks as the child's brain develops, and need cause little anxiety. The indications for surgical treatment are as follows:—

1. *At Birth.* Large indentations associated with signs of cerebral compression.
2. *At Three Months.* (1) Disfiguring indentations outside the hair-line.
   (2) Any indentation over the motor cortex.
   (3) Indentations associated with symptoms such as epilepsy or obvious mental deficiency.
3. *At Three Years.* All indentations irrespective of their position when more than one inch in diameter.

Methods.—A small trephine hole is made at the periphery of the indentation. A suitably curved dissector is then passed through the operative opening and used as a lever to raise the depressed bone. At the end of the operation the trephine disc is replaced so that a defect is not left in the skull (see Fig. 57).

Depressed Fractures

Depressed fractures of the closed type frequently involve large areas of bone and are caused by the head being struck over a broad surface. As in open fractures, they are often comminuted, although the affected bone is rarely broken into small fragments. Occasionally a complete bone is loosened at its suture lines and displaced not only inwards but sideways, so that one of its edges slides between the dura and intact skull.

Closed depressed fractures, even when extensive, are frequently unassociated with signs of local brain damage, and when a patient is conscious it is often difficult to decide whether elevation by operation is necessary or not. When they are not causing obvious symptoms or signs and there is danger in raising them, as for example when they overlie the sagittal sinus, they are better left undisturbed. The decision to operate, of course, will be influenced by the age of the patient and his type of work. A weak skull in a schoolboy is obviously a serious disability, not only because it precludes him from playing games, but it may seriously affect his chances of obtaining employment later in life. In such circumstances it is better to operate. On the other hand, when a man is living a sedentary life and has family responsibilities, it is wiser not to operate.

CLOSED FRACTURES OF THE SKULL

Closed fractures of the skull may be classified as linear, indented or depressed.

Linear Fractures

Linear fracture lines may be short or long, and they may run in all directions over the surface of the skull. They may stop and then start again a short distance away, the continuing line running in the same direction as the initial line, or in a different one. Commonly linear fractures have a stellate pattern. The fracture lines may be part of a depressed fracture and run radially from the periphery of the depression. They may be confined to the base or to the vault, or, as so commonly happens, they involve both the vault and the base. As a rule there is no displacement; however, when this occurs it usually takes the form of widening without depression, and is more often seen in children than in adults. Linear fractures may run into the foramen magnum or across the optic foramina, or into any of the foramina through which the cranial nerves pass as they emerge from the cranial cavity on to the face or neck. Or, again, they may open into the paranasal air sinuses or the middle ear, in which case they cause internal compounding; these latter fractures will be discussed later. Linear fractures are so variable in extent, number and pattern that any kind of detailed classification is profitless.

Treatment.—For undisplaced linear fractures of the vault of the closed type no surgical treatment is necessary. Within a few weeks a fracture line is filled with fibrous tissue, and for most purposes the protective efficiency of the skull is not materially impaired. Despite statements to the contrary, most linear fractures heal by bony union. This takes about twelve weeks in a child and from one to three years in an adult. When fractured surfaces are separated by more than a few millimetres fibrous union is the rule, but even in these cases isolated strands of bone often form and radiological evidence of fracture disappears. "Springing" of a suture is equivalent to a linear fracture and is often seen at the occipito-parietal junction. Spicules of bone projecting from the inner table for more than half-inch should be removed. This is done by cutting out the affected segment of bone with a trephine of suitable size. The spicule is then removed by a chisel or nibbling forceps and the skull repaired by pressing the bony disc back into position. *It is unnecessary to keep a patient with a simple fracture of the skull in bed for more than a few days. Indeed it is a mistake to call undue attention to its presence, owing to the danger of encouraging some kind of troublesome functional overlay* Occasional observation, however, is necessary in order to make sure that an extradural clot does not form and compress the brain.

The main difficulty in this type of case is to decide when a patient may take up his ordinary mode of life.

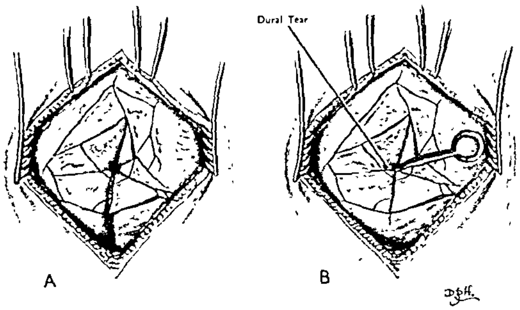
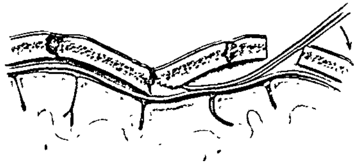


FIG. 58

The specific indications for operative treatment are as follows:—

1. When a patient is unconscious and thought to be suffering from cerebral compression.
2. When there are signs of underlying brain damage, such as hemiplegia or aphasia, or when a patient has persistent symptoms of headache and giddiness.
3. When a fragment of bone is thought to have pierced the dura. This judgment depends on the shape of the bony fragment, on its angle of tilt and on the amount of depression. Fragments depressed for more than half-an-inch, those lying end on, or those obviously spiculated should be elevated.
4. Cosmetic considerations are important not only in women but also in men. Depression and loss of confidence may often be traced to an inferiority complex caused by brooding over a physical disability which is noticeable to other people. This functional complication should never be overlooked, as it can often be corrected by repairs of the skull.

(See Figs. 59, 60, 61.)



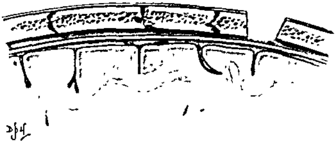


FIG 57

FIGS. 57 and 58

Raising of an Indentation and Exploration of the Dura

In funnel shaped depressions, though the bone is broken the fragments are not

the cortex is apt to lead to epilepsy

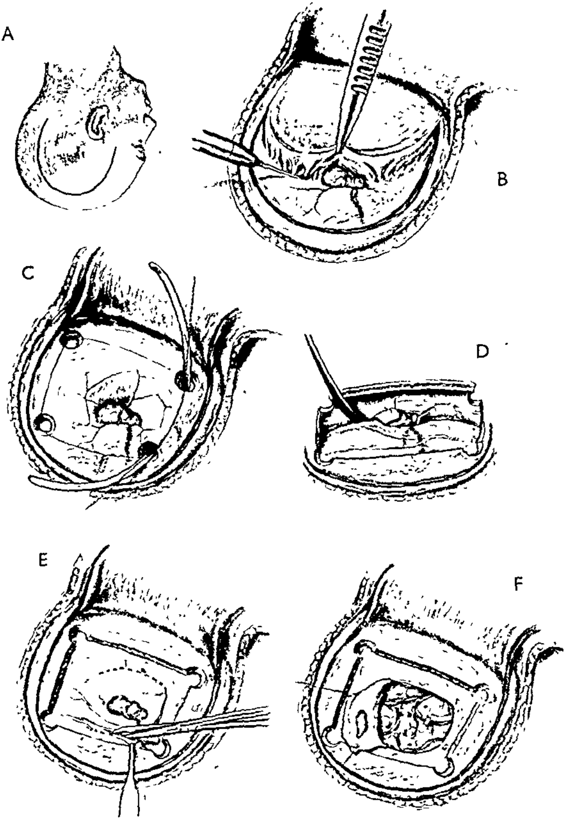


Fig. 60

Repair of Penetrating Non-compound Fracture of the Vault (1)

A The line of the incision. B. Reflection of the temporal muscle and fascia. C. Cutting of the bone flap. D Gentle raising of the bone flap and careful separation of the bone fragments from the dura. E. Opening of the dura mater. F. Inspection of the brain and sealing of ruptured vessels.

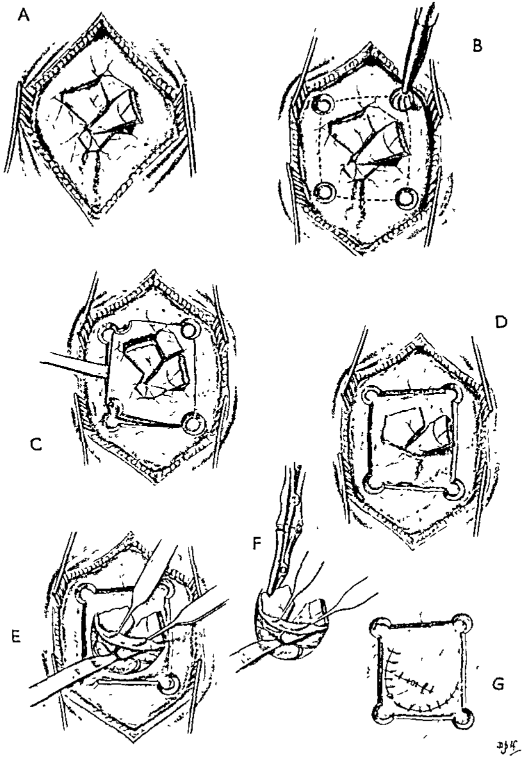


Fig. 59

The Raising of Indriven Fragments

When a bony fragment has been driven deeply into the cerebral tissue, it is much safer to remove it under direct vision than to rock it out blindly If a penetrating fragment is roughly withdrawn there is a danger that a large surface vessel will be torn and serious bleeding result that is difficult to control before the dura is widely opened

A The exposure of the fracture B, C Block resection D. The fragments that pierce the dura are, in the first instance, left *in situ* E, F The deep aspects of the bony spicules are approached a distance G Repair of the dura mater.

OPEN OR COMPOUND WOUNDS OF THE HEAD

Wounds of all types may be classified according to their depths as follows:—

1. Wounds confined to the scalp.
2. Wounds associated with linear fractures of the skull.
3. Compound depressed fractures with intact dura mater.
4. Compound depressed fractures with torn dura mater.
5. Indriven fragments and retained missiles.
6. Wounds opening into the mastoid or paranasal air sinuses.

In all cases, however trivial a wound may seem, a neurological examination must be made to determine whether or not an injury to the brain has occurred. Without neurological information it is often impossible to treat a case correctly; for instance, a large clot of blood may have collected below a linear fracture without the slightest evidence of its formation showing in the wound itself.

Treatment of compound wounds, although primarily directed to excision and repair, must also respect normal intracranial pressures and the general principles of surgery; for example, it is wrong for a patient to be taken to the theatre immediately on admission before possible blood loss has been replaced and treatment for shock carried out.

Surgically, a head wound can be viewed in terms of the scalp, the skull and the brain. Associated injuries should also be taken into account and provision made for their treatment.

The Scalp

Skilled and careful surgery of the scalp is the basis of good results for open wounds of the head. Without proper shaving and cleaning of the scalp the chances of a good result are jeopardised. The importance of shaving the hair widely from the margins of a wound cannot be overemphasised; the field of a wound of the head is still too often left unnecessarily contaminated.

It can be taken as an axiom of surgery of the head that an operation can be regarded as a failure unless the scalp heals by sound primary union. In debridement, contaminated and bruised edges of skin should be cut away sparingly and, if necessary, the skin so mobilised that it can be apposed without tension by sutures placed in the galea and buried beneath the skin edge. When necessary, plastic operations should be carried out without hesitation.

The Skull

Before operating on compound wounds of the skull, detailed X-ray examinations should be made in order to establish, in particular, the number, size and depth of indriven bony fragments or of opaque foreign bodies. When there is a doubt about possible contamination, it is wiser to remove a segment of bone, since repair of the skull is usually a simple matter later should the skin heal soundly and by first intention. It is infection that precludes subsequent plastic operations.

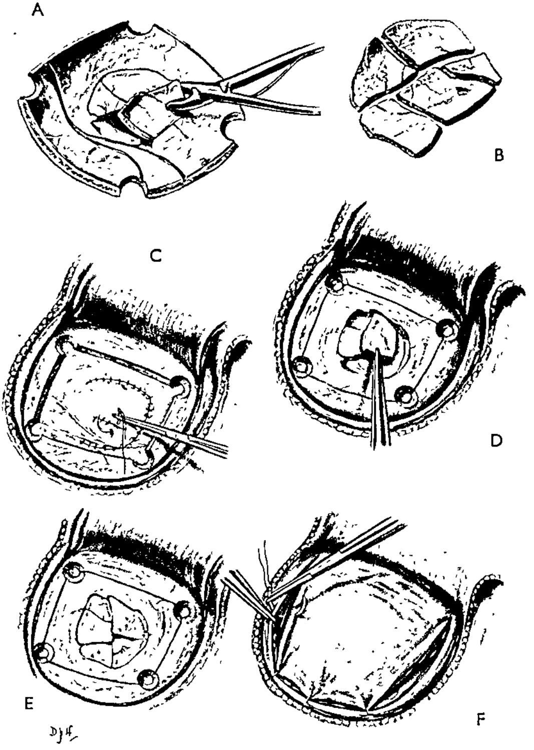


Fig 61

Repair of Penetrating Non-compound Fracture of the Vault (2)

A The bone flap and depressed fragments *in situ* B Grouping of the bone fragments. C Repair of the dura mater D. Replacement of the bone fragments. E. The bone flap and fragments in position F. Reformation of the wound.

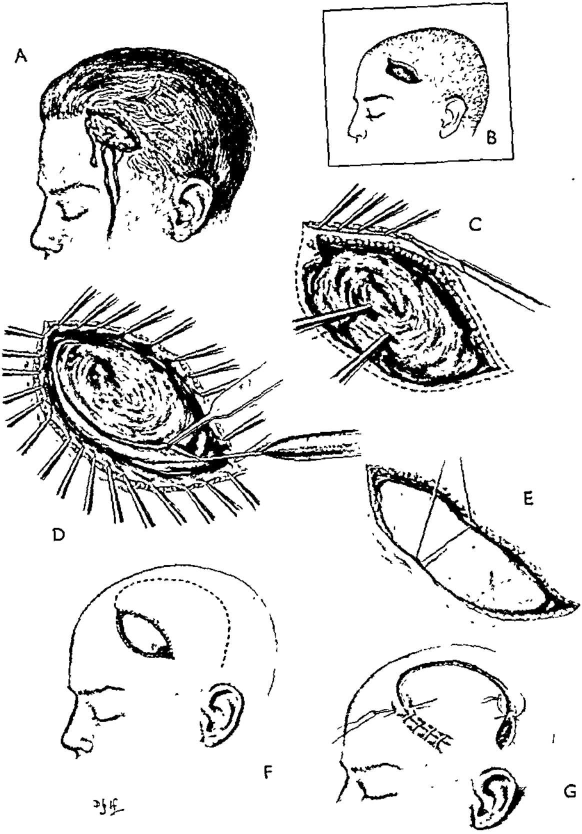


Fig. 63

The Excision and Repair of a Scalp Wound

A. The wound. B In view of the extent of skin loss and the possible necessity for plastic repair, the whole of the head is shaved. C. Excision of the wound edges is sparingly carried out. D. Removal of the contaminated pericranium E. When it is found impossible to close the wound by galeal s[illegible] alone then some plastic measure for clos[illegible]re is necess[illegible]

The Dura

The dura mater acts as an almost impenetrable barrier to the spread of infection into the brain from the bone or scalp. Indeed, dural integrity is of the greatest prognostic value. When the dura is intact, encephalitis and meningitis are unlikely; on the other hand, if the dura has been torn and must be left open, serious cerebral complications are liable to occur. Torn dural edges should be trimmed sparingly, and firmly apposed with sutures. Repair by fascial grafting is necessary when there is loss of tissue and the edges cannot be drawn together.

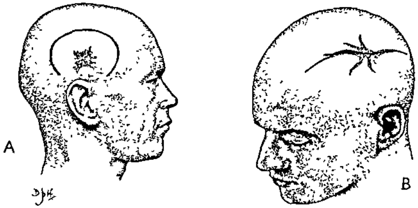


FIG. 62

Wound Patterns and Surgical Incisions

In the exploration of compound injuries of the head, the shape of the surgical incision is, of course, often determined by the pattern of the [illegible] reopening the head for more extensive surgical procedure.

The Brain

Manipulations on the brain should be carried out with the utmost gentleness and care. Treatment is designed to remove dead tissue, extravasated blood, fragments of bone and foreign bodies; care must be taken not unnecessarily to remove brain tissue that is capable of normal function.

To summarise, experience has shown that, in the treatment of open wounds of the head, the best results are obtained by the careful observation of the following principles:—

1. Early and efficient resuscitation before a major operation is carried out.
2. Careful cleaning or complete shaving of the scalp.
3. Early definitive operation: for this adequate neurosurgical facilities must be available.
4. When debridement has not been complete, the scalp should not be sutured.
5. Removal of all indriven bony fragments and pulped brain tissue.
6. Correct usage of chemotherapy, etc.
7. Firm closure of the dura mater.
8. Firm closure of the scalp.
9. Avoidance of cross-infection by correct surgical procedure.

(See Figs. 62, 63, 64–67.)

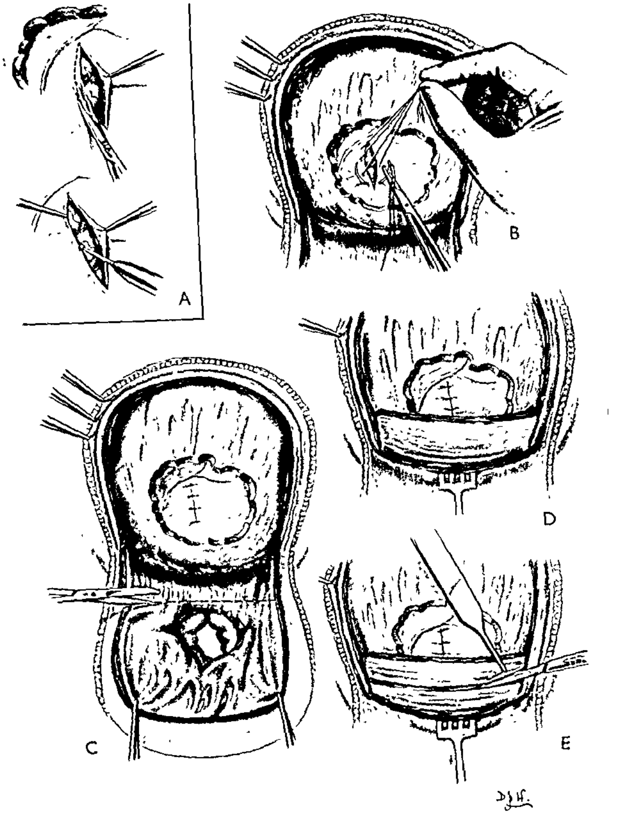


FIG 65

Excision and Repair of a Compound and Complex Wound of the Vault (2)

A. Excision of dural margin and coagulation of a dural vessel B. Suture of the dura C. Excision of damaged and contaminated muscle. D Defect in the bone uncovered by fibro-muscular ' ver E. Reformatio o the fibro m[illegible]

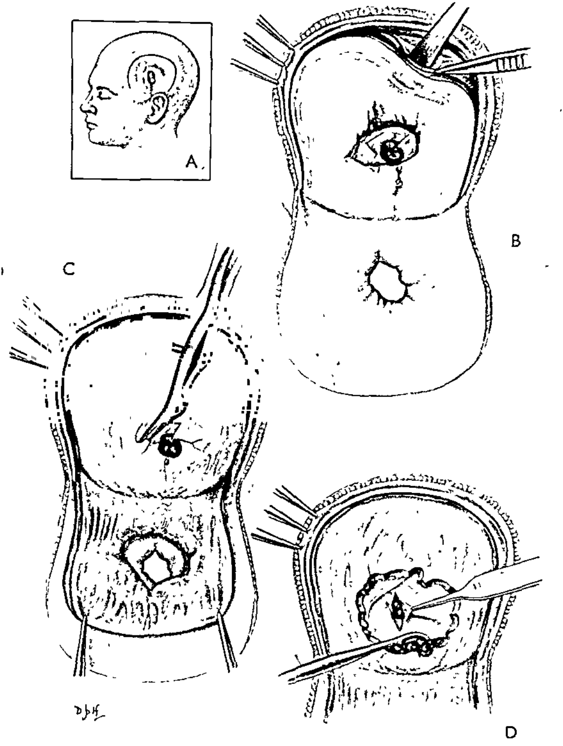


Fig 64

Excision and Repair of a Compound and Complex Wound of the Vault (1)

A. The wound with outline of a semicircular flap used for its exposure. B. Reflection of the fibromuscular layer subperiosteally C Removal of bone. D Exposure of a dural tear and subdural and extradural hæmorrhage.

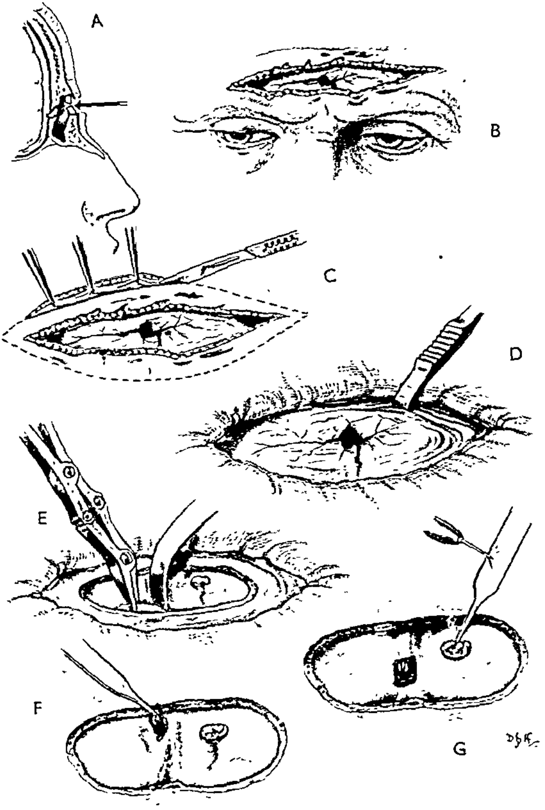


Fig. 67

A Dural Tear Resulting from a Compound Fracture of the Frontal Air Sinus

A. The level of fracture. B The wound from the front. C. Excision of the skin. D Separation of the contaminated pericranium E. Removal of the deeply-placed bony fragments. F. Control of bleeding from the sagittal sinus by means of muscle or Gelfoam graft. G. Diathermy coagulation of a ruptured cortical vess

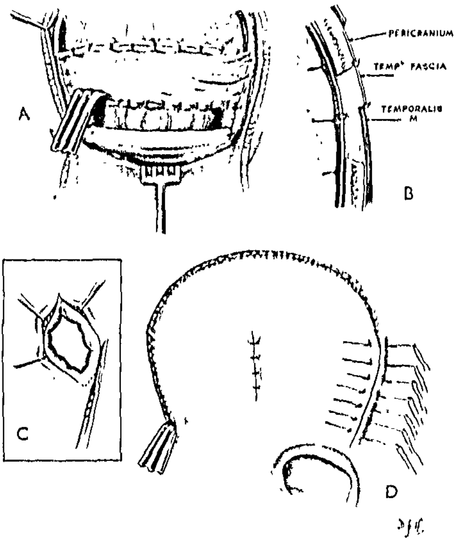


FIG. 66

Excision and Repair of a Compound and Complex Wound of the Vault (3)

A. Repair of the fibro-muscular flap and covering of the bony defect. B. The layers of reconstruction C. Excision of the damaged skin edge. D. Repair of the scalp.

In the treatment of complex wounds of the head, if debridement of contaminated tissue is to be thorough, an adequate exposure of the deeper layers of the wound

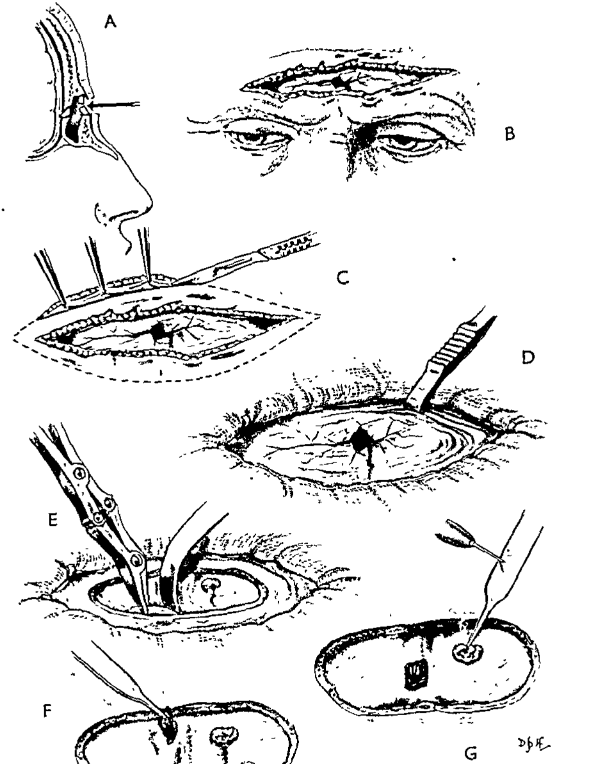


Fig 67

A Dural Tear Resulting from a Compound Fracture of the Frontal Air Sinus

A. The level of fracture. B The wound from the front C Excision of the skin D. Separation of the contaminated pericranium E Removal of the deeply-placed bony fragments F. Control of bleeding from the sagittal sinus by means of muscle or Gelfoam graft G. Diathermy coagulation of a ruptured cortical vessel.

THE BRAIN

The special conditions of the brain demand a special operative technique, the details of which must be observed meticulously if a successful operation is to be performed. Manipulations must be carried out with the utmost gentleness, and great care taken not to injure healthy brain tissue adjacent to the operative field by heavy retraction as a wound track is opened for inspection. Any kind of rough handling of the brain will lead to swelling, which may not only impede surgical procedure but also may prove fatal. All bleeding vessels must be sealed either by coagulation, silver clips, or by muscle grafts, for until this has been done it is useless to close a wound, since a post-operative clot is certain to collect and compress the brain. When a vessel is torn it is unwise to press a finger or a swab heavily on to it to stop bleeding, as consequent displacement of the brain will lead to rupture of distant and inaccessible veins entering the dural sinuses. The bleeding vessel should be isolated by suction and sealed by what seems the most suitable method.

Treatment of a cerebral wound is designed to remove dead tissue, extravasated blood, fragments of bone and foreign bodies, and these intentions must be kept clearly in mind and nothing further attempted if unnecessary damage to healthy parts of the brain is to be avoided. In superficial wounds, foreign bodies may be picked out with dissecting forceps and loose tissue washed away with jets of warm saline projected from a Canny Ryle syringe. When a deep laceration occurs, the wound track should be opened and exposed in its whole length by means of flat metal brain retractors. To do this successfully, skilled assistance and efficient lighting are necessary. Wet lintine swabs placed along the walls of the wound track will protect the brain tissue from damage by the metal retractors. Debridement is then carried out by suction. A glass tube of 3 mm. lumen diameter is used as the sucker nozzle This is passed along the opened wound track and weak suction used, so that healthy brain tissue is not lifted at the same time as damaged matter is removed. Dead brain tissue, extravasated blood and small bony fragments will pass along the lumen of the tube, and these should be caught in a suitable trap, otherwise they will block the sucker. Medium-sized foreign bodies will be drawn into the opening of the glass sucker and may be removed when the sucker is withdrawn. Large bony fragments or missiles may be identified and loosened by suction and then removed with forceps under direct vision. Healthy tissue must never be removed in the hope of getting a clean block resection, as this is likely to lead to spread of infection or to unnecessary neural defects. In particular, debridement in the region of the motor cortex must be done conservatively and with great care if hemiplegia is not to be the result.

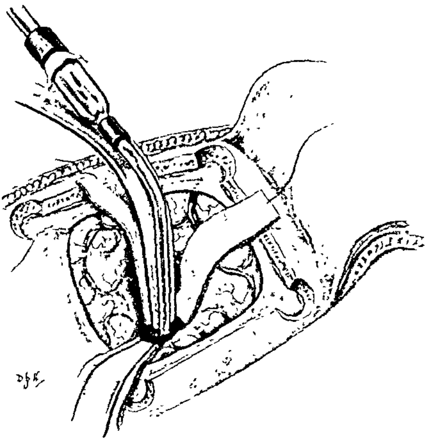


FIG. 68
Debridement of a Wound Track

Retained Missiles

A bullet or bomb fragment is usually deeply embedded in the brain, and whether it should or should not be removed immediately depends on its accessibility. When it can be reached safely along a wound track without infliction of further damage to the brain it should be removed. When a metal missile is deeply placed and not easily accessible it should be left *in situ*, because it rarely gives rise to a brain abscess and its presence does not materially influence the incidence of epilepsy.

Removal of a foreign body at a later date may be necessary if complications such as infection or epilepsy develop. In these cases the operative entrance is determined by accessibility. For example, a bullet is approached from the surface nearest to which it is lying, provided that this is a silent area. It would, of course, obviously be wrong to incise the motor cortex in order to gain access to deep tissues. When infection is already present in the superficial layers of a wound, the only indication for removal of a foreign body is when it is giving rise to an expanding abscess.

DURAL VENOUS SINUSES

Repair of a torn venous sinus is always difficult and often hazardous. Therefore, whenever a depressed fracture is seen to lie over the superior sagittal or lateral sinus, careful and detailed preparations should be taken to anticipate bleeding. The patient's blood-group is determined and a pint of blood obtained pre-operatively. Care must be taken to treat shock, since a further sudden loss of blood might easily take place at the time of operation. The choice of whether the operation is to be carried out under local or general anæsthesia is determined by the condition of the wound and possible injuries elsewhere in the body. When the patient is not shocked and there has not been severe loss of blood, the patient is bled and the blood pressure lowered to a safe minimum: the withdrawn blood can be replaced after the damaged sinus has been repaired and the closure of the wound has been started. Placing and positioning of the patient on the operating table must be such that the pressure in the venous sinus concerned is minimised: the patient's head must be fixed well above the level of his body; when a neurosurgical table is available, the patient should be tilted into a sitting position. The slightest degree of asphyxiation, straining or struggling will dangerously raise the venous pressure and jeopardise a possible favourable result of the operation; local anæsthesia therefore, whenever reasonable, is the method of choice. If pre-operatively it is judged that muscle grafts will be necessary for the dural repair, the anterior compartment of the leg should be opened and muscle taken: an intravenous drip can be set up at the same time. Sheets of Gelfoam will suffice for repair in lesser degrees of sinus injury. At operation the superficial layers of the head wound are excised. Bony fragments are lifted out singly, beginning at the point farthest away from the sinus until the dural tear is fully uncovered. One of the great dangers is that severe bleeding may begin before all the bone necessary for exposure has been removed. When this happens it is best to proceed with the bone removal as expeditiously as possible.

On those occasions when a sinus is found to be completely severed, each end must be clamped with forceps and firmly ligated with stout silk thread. When a tear is extensive but not complete, the edges of the wound should be drawn together with a continuous or interrupted suture and the suture line covered with a muscle graft. When a tear is small it can often be controlled by muscle grafts alone, but these may have to be sewn into position as shown in Fig 69.

FIG 69

Repair of a Torn Dural Venous Sinus

A The wound B Uncovering of the wound C Exposure of the torn sinus D, E Suture of the tear. F Placing of a muscle graft along the suture line. G, H. The muscle graft sewn into position

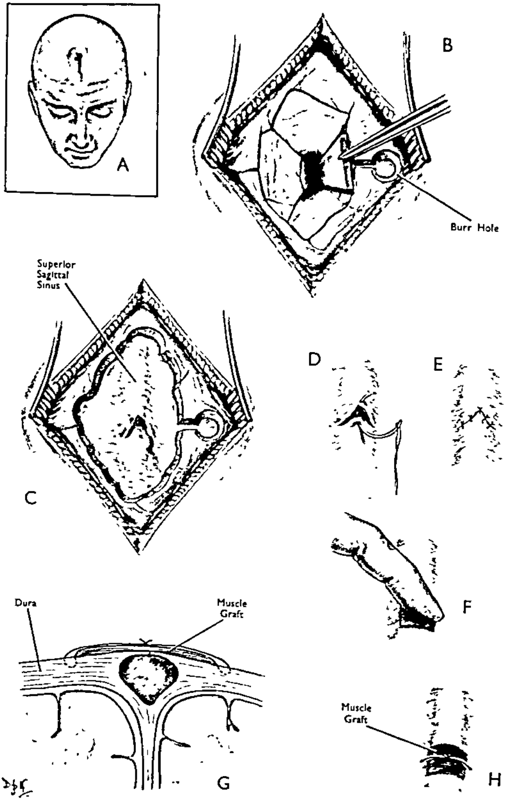

A
B
Burr Hole
Superior Sagittal Sinus
C
D
E
F
Dura
Muscle Graft
G
Muscle Graft
H

FIG 69

CEREBROSPINAL RHINORRHŒA

Leakage of cerebrospinal fluid from the nose may occur immediately after injury or may develop after a latent interval of days, weeks, months or even years.

Theoretically, a compound tear of the dura mater, resulting from fracture of the walls of the paranasal air sinuses, should be explored and repaired at once if serious infection is to be prevented. Few surgeons, however, choose to operate within the first forty-eight hours because—

1. Many of the patients are seriously ill with concussion.
2. It is believed that many cerebrospinal fluid fistulæ heal spontaneously without meningitis supervening.

The absolute indications for immediate operative repair are:

1. Pre-existing infection in the affected air sinus.
2. The onset of sinusitis, osteomyelitis or meningitis.
3. Radiographic evidence of extensive displacement of fractured surfaces.

A fistula that does not appear until a few days or a week after injury is probably produced at the moment of injury but remains blocked for a time by blood clot, by a mucous plug, or by an air bubble. Then, owing to some simple change in the mechanical conditions, such as alteration in the position of the head, a rise in intracranial pressure or absorption of blood, the fistula opens and cerebrospinal fluid escapes.

Why leakages should occur after months or years is much more difficult to understand. Some, possibly, as a result of the pull of cicatrisation of healing processes, are due to widening of a pre-existing but exceedingly narrow fistula which has passed unnoticed. Most probably they are to be accounted for by an aseptic necrosis affecting a local area of the cribriform plate or roof of the frontal air sinus. This process of osteitis dissecans may be the result of ischæmia of the bone, consequent on rupture of its nutrient vessels as the dura (endosteum) is stripped at the time of the accident. If for any reason the dura and mucous membrane covering the affected area of bone on either side become involved in the processes of necrosis, a fistula will result.

Diagnosis is simple. A colourless fluid trickles from the nose in drops, and this discharge may be made more profuse by straining or by bending the head forward. Occasionally a leakage of cerebrospinal fluid may be confused with a watery discharge, either from the lachrymal gland or mucous membrane of the nose. Since cerebrospinal fluid is the only fluid which contains sugar, a chemical analysis in these cases is all that is necessary to distinguish cerebrospinal fluid from secretions arising within the nose.

In these delayed cases the side of the nose from which the discharge comes may lateralise the fistula, and intranasal inspection will show whether it is situated anteriorly or posteriorly. When the fluid is seen to be trickling from above the middle turbinate, the fistula passes through the ethmoid or sphenoidal air cells, but when the fluid drips from beneath the anterior end of the middle turbinate the fistula is more anteriorly placed and passes through the frontal sinus.

If necessary, methylene blue injected into the ventricles will definitely determine the presence of a fistula, since in such cases the discharge from the nose will be coloured blue.

Treatment.—In the acute stages of injury when open operation has been decided upon, it is usually safer to take down a bifrontal flap in order to explore both sides of the frontal fossa. Bilateral exposure is usually necessary because, as a rule, it is not possible to diagnose the side of the fracture and dural tear with certainty. The disadvantage of bilateral exposure is the likelihood of damaging both olfactory nerves and destroying both smell and taste. In the later stages of fistulæ it is usually possible to determine whether one or both sides are affected, and if one side which it is.

Since it is in delayed cases of cerebrospinal rhinorrhœa that operation is most specifically indicated, we will illustrate the unilateral approach. Whether a unilateral or bilateral flap is taken down, the fistula may be approached and repaired either intra- or extra-durally. Our method is to approach the fistula extradurally (see Fig. 71, G) and to sever and repair the opening both in the bone and in the dura. When it is not possible to find the fistula extradurally, the dura is opened and explored from the inside, as shown in Figs. 70 and 71.

The technique is to sever the funnel of the fistula and to repair the opening either by fascial grafts or by suture. When the dural tear has passed so far posteriorly that it is difficult to insert sutures, either to appose the dural edges or to fix a fascial graft in position, fixation of the graft can be attained by the technique illustrated in Fig. 72.

The above remarks also apply to the rarer condition of otorrhœa, and the repair of an aural fistula is illustrated in Fig. 73.

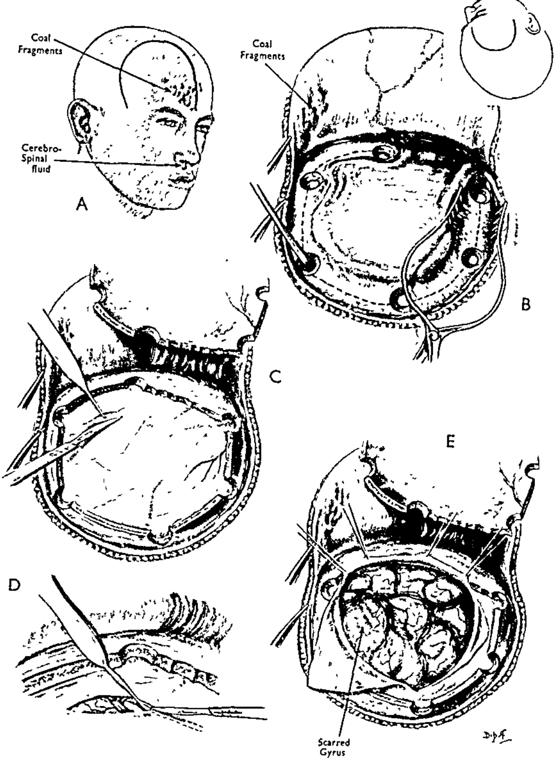


Fig 70

Cerebrospinal Rhinorrhœa (1)

A. The line of the incision in the unilateral approach B. Reflection of the skin and preparation of the bone flap C Opening the dura mater D The brain is protected as the dura is opened. E. Exposure of the frontal pole of the brain.

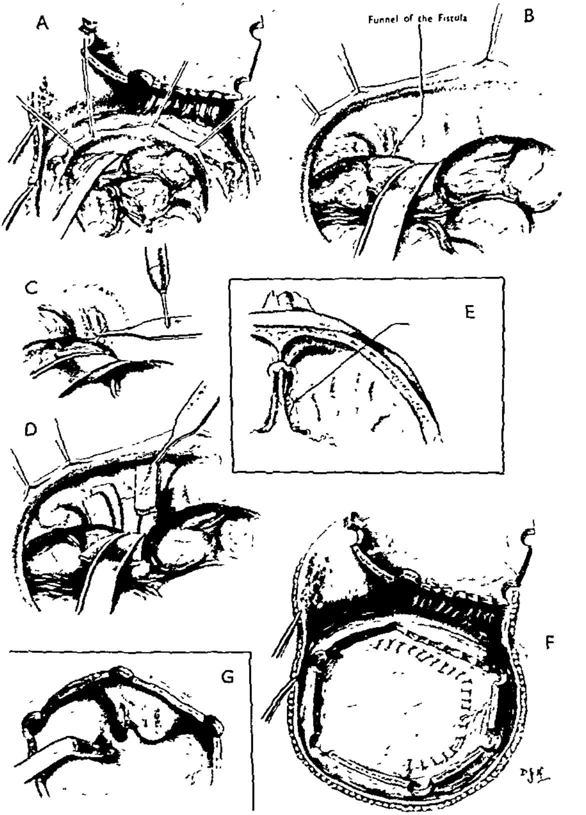


FIG. 71

Cerebrospinal Rhinorrhœa (2)

A. Lifting of the brain from the floor of the frontal fossa. B. Exposure of the funnel of the fistula and the *fracture line in* the floor of the frontal fossa. C. Division of the funnel of the fistula. D. Repair of the opening of the fistula with pledgets of Gelfoam. E. The site of the fracture. F. Closure of the dura mater. G. Exposure of the fistula by the extradural approach.

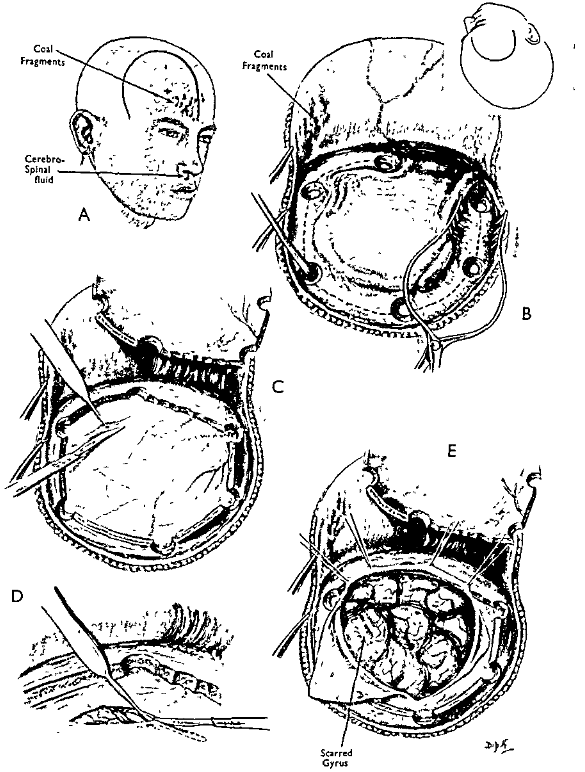


FIG. 70

Cerebrospinal Rhinorrhœa (1)

A The line of the incision in the unilateral approach B Reflection of the skin and preparation of the bone flap C Opening the dura mater D. The brain is protected as the dura is opened E. Exposure of the frontal pole of the brain

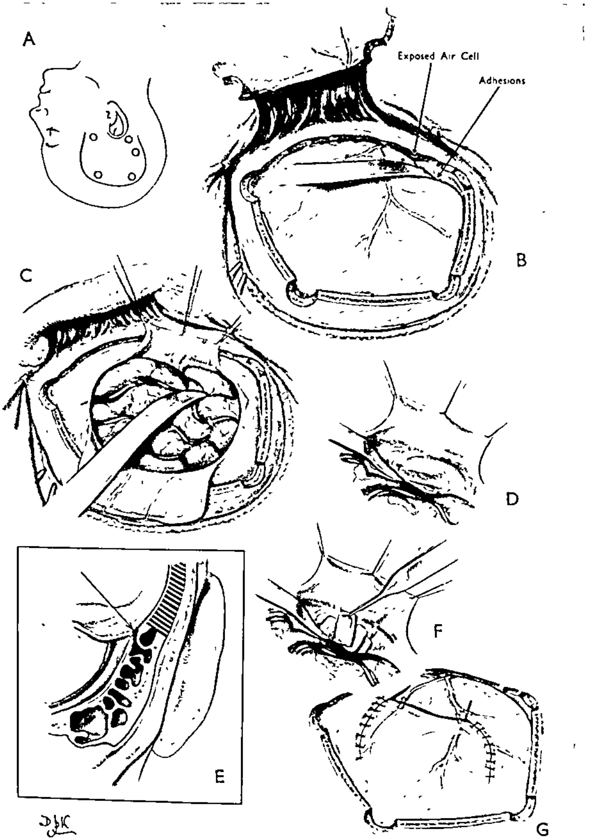


FIG. 73

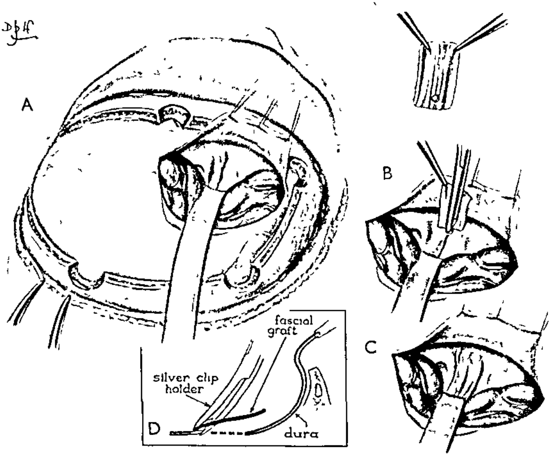


FIG. 72

Cerebrospinal Rhinorrhœa (3)

A dural tear may run so far posteriorly that it is impossible to anchor a fascial graft by suture; in such cases, the graft may be anchored by the technique illustrated in the above drawing
A Exposure of the tear intradurally. B, C, D. Fixation of the graft by the silver clip method.

FIG 73

Cerebrospinal Otorrhœa

A. Line of skin incision and position of t
down to the floor of the temporal fossa
lobe. C Exploration of the floor of the
mater E Site of the dural tear F P
G. Repair of the dural incisions

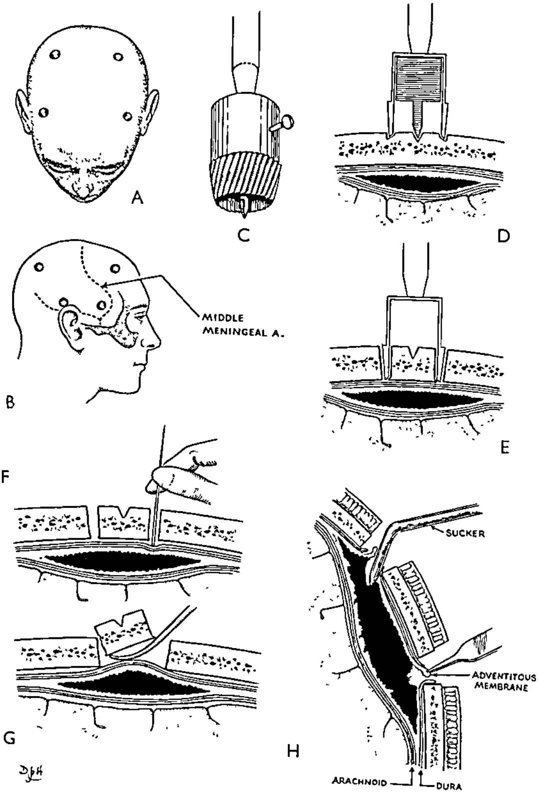

A
C
D
MIDDLE
MENINGEAL A.
B
E
F
SUCKER
ADVENTITOUS
MEMBRANE
G
H
ARACHNOID
DURA

FIG. 74

CHRONIC SUBDURAL HÆMATOMATA

Chronic subdural hæmatomata have aroused widespread interest, not because of their frequency, which in fact is less than 1 per cent in any clinical series of acute cerebral trauma, but rather because of the problems of their development and, to a lesser extent, on account of the excellent results of treatment by drainage (Fig. 74).

The condition "pachymeningitis hæmorrhagica interna" has been recognised at least since the middle of the last century, and was fully described by Virchow under the term "hæmatoma dura matris". None the less, it remained for Trotter to stress the hæmatoma's *traumatic origin and to show that it often occurs after a very slight knock on the head.*

The course of events in the development of any chronic subdural hæmatoma is complicated. A vessel, probably a vein, ruptures and then seals, and the resulting hæmatoma becomes enveloped in a fibrinous membrane which later is organised by mesothelial invasion. The part of the membrane nearest the arachnoid remains thin and non-adherent, whereas the outer part thickens and becomes attached to the dura and is impossible to strip without rupturing numerous small blood vessels, which is a point of some surgical importance. At some phase in its life-history the encapsulated clot begins to swell, but why this happens is not known. It has been suggested that small repeated bleedings could account for it, and this view is supported by the fact that at autopsy cerebral veins have been found either attached to the capsule or thrombosed within the clot. The adventitious membrane enveloping the clot becomes highly vascularised, and oozings from the newly formed vessels may account for any increase in size of the hæmatoma: it is, in fact, quite common to find fresh blood within the clot, even after a considerable period has elapsed since the injury. A popular and attractive theory is that the membrane of the hæmatoma possesses semi-permeable properties, and that, as the clot disintegrates, its molecular concentration will increase. This will cause a rise in osmotic pressure, with the result that cerebrospinal fluid will be drawn through the semi-permeable membrane by the processes of dialysis. In favour of this hypothesis are the varied contents which may be found in the hæmatoma. These may be partly solid and partly fluid, or they may be wholly fluid. Also the fluid may be black and viscous, or it may be light brown and watery. Furthermore, the protein content of the fluid obtained from these hæmatomata actually increases as they break down. On those occasions when the hæmatoma is not drained or removed by dissection it may fibrose or even calcify.

FIG. 74

Draining of a Chronic Liquid Subdural Hæmatoma

A, B Position of trephine holes in search of a surface hæmorrhage without localising signs. C. Trephine. discs of bone can be replaced in negative explorations D First part of cut is facilitated with centre pin in position E The deeper cuts are made after the centre pin has been removed F. Needle tapping for the dura. G. Elevation of disc with curved dissector H Removal of clot—drainage is necessary till cavity is obliterated by swelling of the brain

Infection of Loose Fragments

In the debridement of large compound wounds it is sometimes justifiable to leave loose fragments of bone in position so as to minimise the resulting defect. If at any time, when this has been done, infection occurs, the wound should be reopened immediately and the loose fragments removed. After packing of the wound with sulphonamide, large skin flaps may be loosely resutured if an adequate opening, say one inch or so, is left for drainage. Small fragments of bone are often inadvertently left behind in unskilled debridement, and these commonly give rise to infective complications long after the scalp wound itself has healed. Such fragments, of course, should be removed surgically (Fig. 68).

Sinus Formation

As a rule it is no good waiting for chronic sinuses of the scalp to heal by conservative measures. It is best to open them widely and to remove the cause of the persistent infection; often a foreign body will be found and its removal will effect a cure.

SPREADING OSTEOMYELITIS OF SUBACUTE OR CHRONIC TYPE

An indolent osteomyelitis may, as the result of thrombophlebitic processes, travel extensively along the diploic spaces. At one point the outer table may necrose; here an external fistula may form. At another point the inner table may sequestrate; here an extradural abscess may form. Finally, the whole segment of the affected bone takes on the classical worm-eaten appearance, the X-ray showing a fluffy area of irregular rarefaction enclosing dense sequestra.

Treatment is difficult because—

1. Large areas of bone are affected.
2. It is impossible to know by clinical or radiographic means just how far the inflammatory processes extend.
3. The overlying skin is unhealthy; it is riddled by multiple sinuses and in places may be adherent to the bone.
4. The bacteria concerned are tenacious, or the tissues have a predisposition or lack of resistance to the organism concerned. Such conditions are very similar to tubercular infections of bone in their persistency.

Theoretically, the best treatment is complete removal of the affected segment by block resection through healthy bone. The objections to this method are:

1. A large defect in the skull would be the result.
2. The danger that a large skin flap necessary for the exposure would not heal.
3. The difficulty in knowing how much bone to resect in order to cut beyond the boundaries of the infection.
4. The danger that infection may start in the edge of the cut bone, however wide a resection be made.

TRAUMATIC SEPTIC OSTEOMYELITIS

Acute fulminating osteomyelitis associated with toxæmia, septicæmia or pyæmia, such as arises in the metaphysis of long bones in young boys, is almost unknown in the vault of the skull. Occasionally a severe osteomyelitis of the frontal bone may result from an acute suppurative frontal sinusitis, but this rarely follows injury. Occasionally in closed injuries a piece or flake of bone may necrose and become infected via the blood stream. As a rule, traumatic osteomyelitis is of the chronic or low subacute type, and results from direct contamination of an open wound of the vault, or from internal compounding when the paranasal air sinuses are opened into.

Of localised osteomyelitis there are three clinical types:

1. A wound that has apparently healed becomes sensitive to pressure. Then a swelling appears, a length of the scar opens and a discharge of pus occurs. There are no signs of toxæmia, but the wound in spite of careful dressings continues to discharge. Radiography, though often negative, may show the presence of a foreign body or of a superficial erosion of the outer table. In such cases the wound should be widely opened if it does not heal rapidly. Commonly, foreign bodies, such as dirt, grit, hair or pieces of clothing, will be found in the deeper tissues. These are removed and granulated tissue is cut away. If the surface of the bone is roughened it should be scraped and small sequestra removed. The wound is then packed with penicillin powder and allowed to heal from below.

2. Sometimes as a result of infection a wound is not consolidated by primary healing. When infection is thought to arise in the deeper tissues, as judged by a copious amount of discharge and surrounding œdema, then the wound should be widely opened and treated as in (1) above To wait for any length of time in the hope *that the wound will heal without further intervention is usually a waste of time.* Simple infection of the edges of a skin wound shows signs of improvement within a few days

3. Occasionally the edges of a defect in the skull become infected, resulting in a sclerosing osteitis and a persistent discharge of pus through one or more fistulæ. In these cases radiography shows that the edges of the bone are irregularly sclerosed At times discrete sequestra are demonstrated. Treatment consists either in block resection of the infected bone or removal by piecemeal nibbling. In most of the cases it will be found that conservative measures only are necessary to clear up the discharge. Whichever method is used when operating, great care must be taken not to pierce the dura, as meningitis may be the result. To avoid opening the meningeal spaces the dura should be separated carefully from the bone by means of a curved dissector. The amount of bone to be nibbled away can be judged by the extent of the dural granulation tissue, which must be completely uncovered in all directions. Unhealthy granulation tissue is removed by gentle sweeps with a gauze swab.

THE REPAIR OF DEFECTS IN THE SKULL AND EXCISION OF MENINGO-CEREBRAL SCARS

The disability caused by a calvarial defect is not necessarily serious, and depends on its size, position, and the part it plays in the production of post-traumatic epilepsy. A defect naturally is much more serious when the underlying dura is open and the brain is adherent to the scalp than when the dura is intact, as drag on the cerebral cortex is so prone to cause headaches, dizziness or epilepsy. It is often difficult to decide, particularly in the absence of symptoms, whether or not a repair of the skull is necessary, and it will be helpful to keep the objects of treatment clearly in mind. These are fivefold:

1. For the cure or prevention of traumatic epilepsy.
2. For protection of the brain.
3. For cosmetic purposes.
4. For relief of giddiness and other symptoms consequent on instability of the cerebral circulation.
5. For psychological reasons.

General Considerations

Repair of a calvarial defect must never be considered until a wound is free from infection and the skin soundly healed over it. An unhealthy-looking scar, repeatedly scabbing in spite of treatment, is suggestive of infection and must be regarded as such. After a few months, radiography will often give valuable information regarding the presence or absence of infection, since in a clean wound the margins of the bone will be sclerosed, whereas when infection is active the bony edges may be fluffy or sequestra may show. It is always wiser to wait two or three months in doubtful cases before operating, because a failure will further delay or jeopardise the chance of later success.

A graft *or a prosthesis can be fitted either by the onlay or inlay method* (*Figs.* 76, 77), the latter, of course, fitting more snugly. Bone taken from the outer table of the skull, from the patient's or, in the case of a child, from the mother's rib, from the tibia or from the ilium, remains a satisfactory material for the repair of small defects inside the hair-line. In large defects about the vault and in complicated defects outside the hair-line, where cosmetic considerations are of importance, it is convenient to use an alloplastic material such as tantalum or acrylic resin (Fig. 78). The advantage of an alloplastic material is that the prosthesis can be moulded accurately to the shape of the defect before it is fitted and sewn, nailed or screwed into position. Tantalum is a bluish-white material which is supplied in sheets. It is easily malleable and can be sterilised by heat. It is the material that we choose to use. Before the operation, an impression of the defect is taken through

In extensive infections it is probably wiser to approach the affected bone by means of a series of vertical parallel cuts through the scalp and to undermine the rectangles of skin so formed (Fig. 75). In this way an unlimited area of the skull can be exposed without the danger of the skin retracting in the same way as when a flap fails to heal. The whole of the

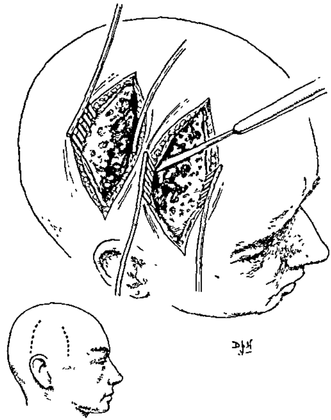


FIG. 75

The Surgical Approach to Spreading Osteomyelitis of the Skull

external table is then removed over infected diplœ; granulation tissue is scraped away and necrosed areas of the inner table excised The wound is then packed and allowed to granulate. Later, a course of sunlight or deep X-ray therapy is applied to the head. Medical measures to bolster up the general health are also important. In fact, this is the type of infection which often necessitates treatment in a sanatorium.

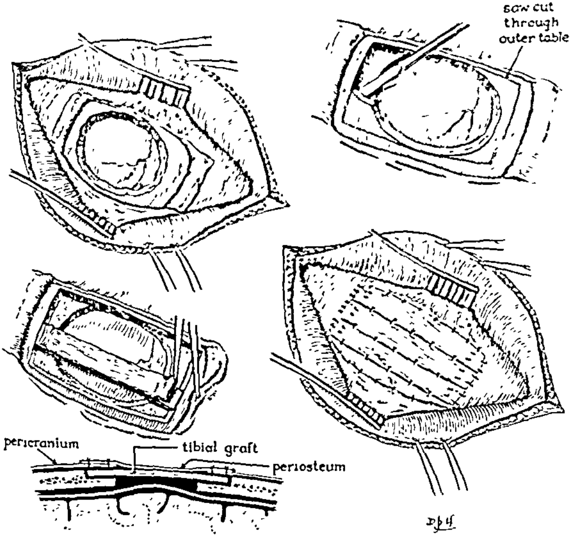


FIG. 77

Repair of a Defect of the Skull with a Tibial Graft by the Inlay Method

complicated by the processes of infection, the incidence of epilepsy is greater in penetrating than in non-penetrating types of injury. Of all the conditions likely to lead to epilepsy, the attachment of the cortex of the brain to the overlying skin, consequent on superimposed and calvarial defects, is the most important.

Treatment consists of clean excision of the scar down to its depths and, if necessary, as far as the ventricular wall itself. In dural losses the gap is repaired by fascia lata grafts taken from the side of the thigh (Figs. 79, 80, 81).

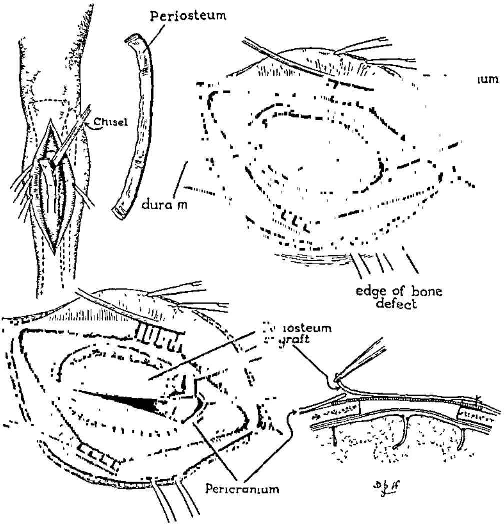


FIG 76

Repair of a Defect of the Skull with a Tibial Graft by the Onlay Method

the skin in wax and, from this model, the tantalum is shaped pre-operatively either by beating or by pressure, so that only minor adjustments of shape are necessary at the operation itself.

Epilepsy and Meningo-Cerebral Scars

Brain scars are believed to be the most common cause of epilepsy, which results directly from trauma and which is not merely precipitated by the injury itself. As meningo-cerebral scars most frequently result from penetrating wounds, and particularly those

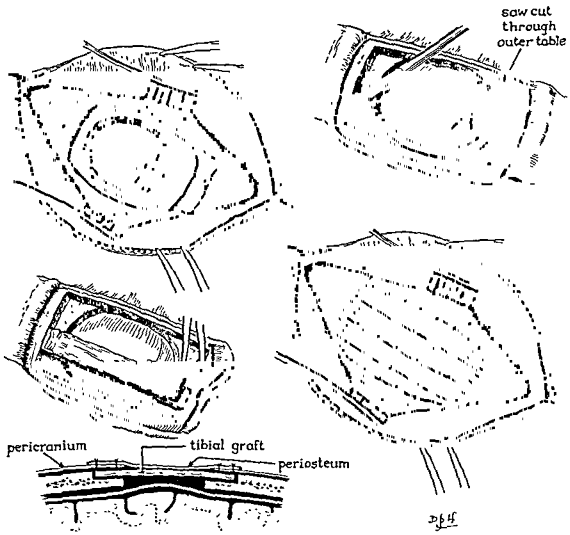


FIG. 77

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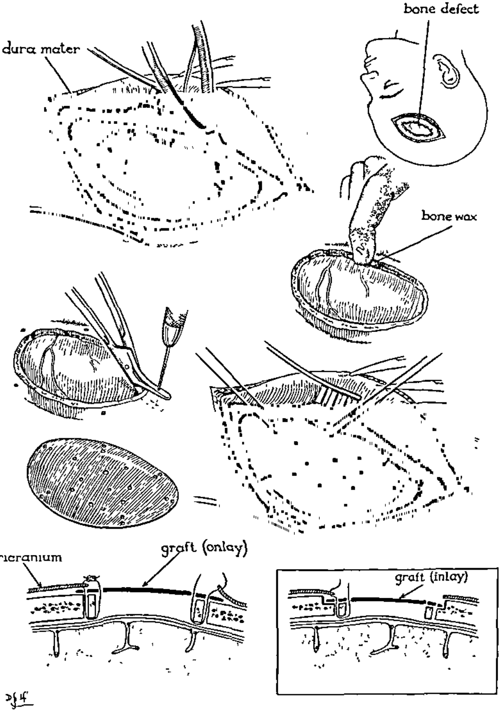

FIG. 78

Repair of a Defect of the Skull by a Plate of Tantalum

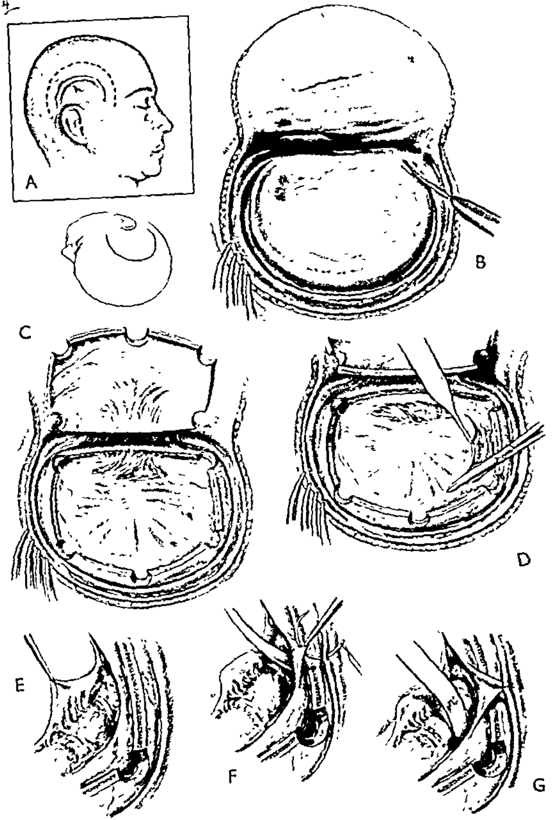

Fig. 79

Excision of a Meningo-cerebral Scar with Dural Loss (1)

A. The line of skin incision. B. Cutting the fibro-muscular flap. C. The meningo-cerebral scar. [illegible]

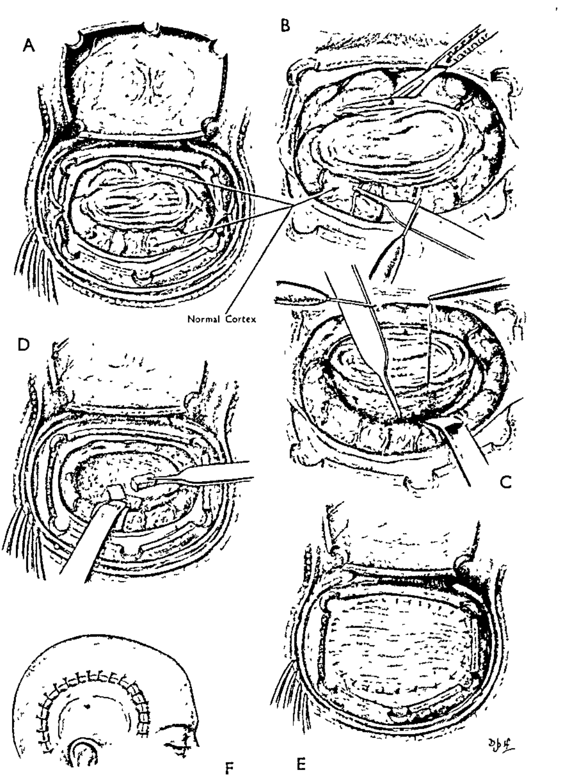

FIG. 80

Excision of a Meningo-cerebral Scar with Dural Loss (2)

A An island of dura mater was left attached to the cortex B, C. Excision of the meningo-cerebral scar. D Hæmostasis by Gelfoam pledgets E Repair of the dura mater with a fascia lata graft. F Reformation of the skin.

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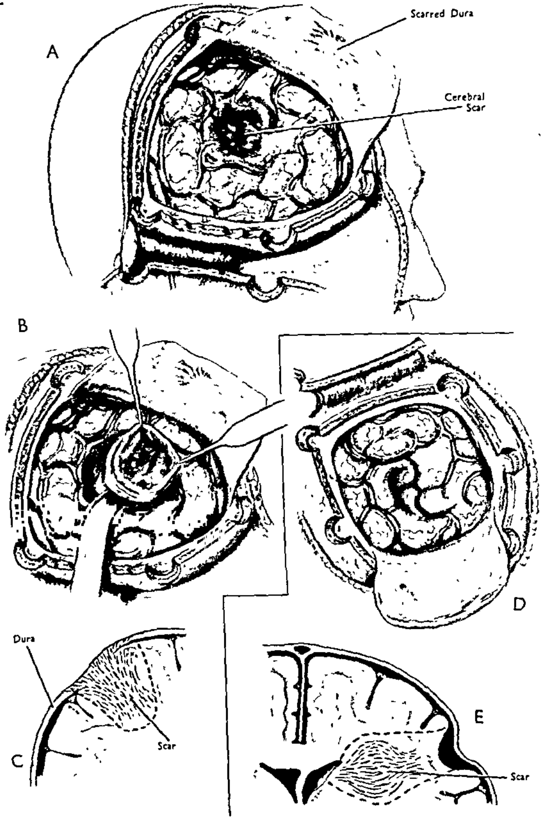

FIG. 81

Excision of Meningo-cerebral and Cerebral Scars without Dural Loss.

A. The appearance of a meningo-cerebral scar where there has been no dural loss. B Excision of the scar. C. Diagram showing depth of resection. D. The appearance of a cerebral scar without meningeal adhesions. E. Depth of resection commonly needed in subcortical • ~ rs

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